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Fishery Leaflet 364

Washington 25, D. C. January 1950

THE MUSSEL RESOURCES OF THE NORTH ATLANTIC REGION

PART I--THE SURVEY TO DISCOVER THE LOCATIONS AND AREAS OF THE NORTH ATLANTIC MUSSEL-PRODUCING BEDS

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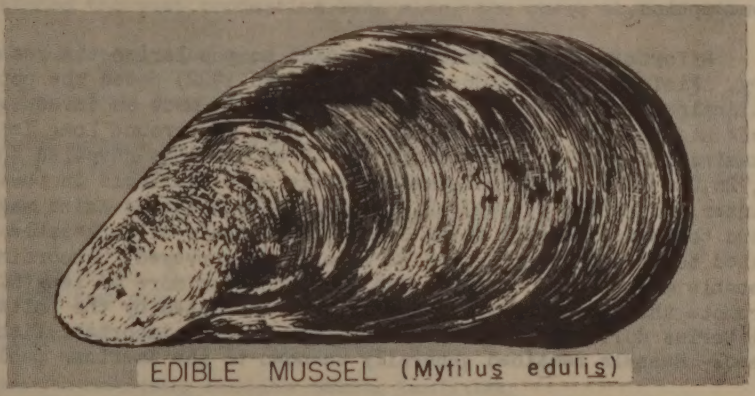
This is the first of three papers discussing the World War II promotion of the North Atlantic mussel fishery. The present article is primarily concerned with the quantitative results of a survey of the productivity of mussel areas.

INTRODUCTION

During the recent war, the fishing industry had the problem of increasing its production despite relative shortages of manpower, equipment, and materials. One of the ways of efficiently augmenting the catch of fish and shellfish was to utilize species ordinarily disregarded. One of the probable sources of sea food was the edible mussel (Mytilus edulis), which is so common along the North Atlantic Coast of the United States. This species can be harvested during that time of the year when the small-boat fishery is least active. In the late winter and the spring months, the mussels are in good condition for marketing, as it is then that they reach their fattest condition, and in this period other fishing activities are at a low level.



EDIBLE MUSSEL (Mytilus edulis)

The mussel, although relatively unknown to the American public, has attained great popularity in Europe. Large quantities have been consumed in European countries for hundreds of years.

The annual English, Welsh, and Scotch production of this shellfish, as recorded in the statistical reports of the British Ministry of Agriculture and Fisheries, averaged about 19 million pounds ("in the shell" weight) for the 15-year period between 1924 and 1938. In addition, large quantities of the shellfish are imported or landed by foreign boats. For example, 10½ million pounds in 1930 and 12 million pounds in 1932 were brought into Great Britain. Considering the imports and local production, nearly 30 million pounds were used annually in Great

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Note: This leaflet supersedes Sep. 239, a reprint from Commercial Fisheries Review, September 1949, pages 1-10; October 1949, pages 8-20; and November 1949, pages 3-13.

Britain during these years. Most of the mussels are consumed as food; some are used as bait in the long-line fisheries.

France consumes much greater quantities of mussels, and so important is this shellfish that extensive artificial cultivation has been practiced for several centuries in that country. Lambert (1935) states that generally France consumes about 143.3 million pounds, of which about one-third comes from natural beds, one-third from mussel "farms", and the balance imported from Holland.

The mussel production for 1933 in Holland, which consumes only small quantities of this shellfish, was about 144.5 million pounds, of which 44.1 million pounds were used for duck food, 4.4 million pounds for fertilizer, and 90.4 million pounds were exported to Great Britain, Germany, Belgium, and France, according to Lambert. The latter two countries absorbed about 95 percent of the Dutch exports. During 1917 and 1918, Holland shipped over 2,204,600,000 pounds of mussels to Germany, according to estimates of some Dutch mussel culturists interviewed by Lambert.

In the United States, mussels have been utilized only slightly. The records of the United States Bureau of Fisheries and the Fish and Wildlife Service show that during the 10-year period (1929 to 1940), the annual production of the mussel fishery averaged 200,000 pounds of meats, or to make the figure comparable to those given for Great Britain, less than 1,000,000 pounds ("in the shell" weight). About 75 percent of the Atlantic Coast mussels were landed in New York City. As a result of the recent war, a fishery for the ribbed mussel (Modiolus demissus) has been prosecuted in the middle Atlantic and Chesapeake Bay areas, but these mussels have been used in the preparation of vitamins for poultry, rather than for human consumption.

Efforts have been made in the past to popularize the sea mussel in this country. Field (1910a, 1910b, 1911, 1913, and 1922) noted the potentialities of an Atlantic Coast mussel fishery. Field in 1917 made an investigation of the mussel beds at Plymouth Harbor, Narragansett Bay, and around Long Island, New York. An examination of 19 localities in the three sections revealed that an estimated 2,726,000 bushels of marketable mussels were available in these areas during the winter and spring of 1917-18. In 1918, the coast of Maine was surveyed from Portland to Eastport and a total of 127,000 bushels of marketable mussels were estimated to be available in the 32 localities surveyed. According to Field, a marketable mussel was one which was two inches or more in length. Some attempts to promote the use of mussels as food were initiated by the United States Bureau of Fisheries during the years 1917 to 1919, but an important fishery never materialized. Mussels remained generally unknown to the American public.

When renewed efforts to develop a mussel fishery were under consideration in 1942, it was thought that the consumer's reaction to the product should first be evaluated. Fresh, frozen, and canned mussels, prepared in a variety of ways were served to a considerable number of people by members of the Fish and Wildlife Service. The mussels, with the exception of several frozen lots, were judged to be excellent when served in chowder, fried, or eaten raw as a cocktail. The first general test of the public's reaction to mussels was sponsored by the Massachusetts Division of Marine Fisheries. At the 1942 annual fair in Brockton, Massachusetts, steamed mussels on the half shell were served at the marine fisheries booth. The consumption of over two tons of mussels at the fair indicated that the public found the shellfish acceptable. In addition, representatives of the Massachusetts Division of Marine Fisheries prepared mussel chowders which were served in the commissaries of several Massachusetts defense plants. The enthusiastic acceptance of the mussels was most encouraging. The Division representatives

reported that the few individuals who did not enjoy mussels were those who did not like shellfish in general. It was felt that once consumers were acquainted with the excellent flavor of the mussels a demand for this new product would soon be established.

Mussels are an excellent source of protein, are rich in vitamins (riboflavin and Vitamin A), iron, copper, and iodine, and contain magnesium, phosphorus, and calcium; therefore, they would be a valuable addition to the diet. The possibilities of increased use of mussels in this country were recently stated by Herrington and Scattergood (1942, 1943) and Loosanoff (1942, 1943a, and 1943b).

As the mussel resources had been but slightly utilized along the North Atlatic coast, there was little recent available information concerning the supply of the species. Data from Field's survey of 1917-18 were available, but it was not known whether his estimates of productivity were applicable to the 1942 supplies, or whether the beds which he examined still existed. In order to determine the extent of the supply and the possibility of developing a fishery, it was necessary to make a preliminary survey of the mussel resources and the factors affecting their utilization. No attempt was made to make a complete survey.

Because of the limitations in time, it was not possible to cover the entire North Atlantic region. However, the principal mussel-producing areas between Point Lepreau, New Brunswick, and Rockland, Maine were examined. Parts of the New Hampshire and Massachusetts coastlines also were examined. Available data indicated that these areas included the most productive beds along the coast at that time.

The mussel survey was planned to provide the following information:

1. The locations and sizes of the principal mussel beds.
2. The total contents of the beds in terms of quantity and size of mussels.
3. The yield in pounds of meat per bushel for each area and season.
4. The quantities and sizes of pearls found in mussels taken from each area.
5. Practical methods of harvesting mussels.
6. Information concerning available canning facilities, boats, and manpower.

The mussel surveys of 1942 and 1943 were made possible by the active cooperation of the Maine Department of Sea and Shore Fisheries, Maine Development Commission, New Hampshire Fish and Game Department, Massachusetts Division of Marine Fisheries, Fisheries Research Board of Canada, Canadian Department of Fisheries, and interested cannery operators and fishermen. Without this assistance much less ground could have been covered with the time and personnel available.

An examination of the mussel resources of Southern New England was carried on by the United States Fish and Wildlife Service in cooperation with the Rhode Island Department of Conservation, and the Connecticut State Board of Fish and Game. The preliminary results of the survey in southern New England are given by Loosanoff (1943c).

MUSSEL SURVEY

The object of the survey was to locate and examine the most important mussel beds in the various sections. In many localities, small areas which might possess enough mussels to be worthy of a fisherman's attention were not covered; therefore, the survey represents the very minimum extent of the supply.

Local information from fishermen and fishery wardens was of great assistance in locating the mussel beds in many localities, although in general the mussel was not of any interest among the residents along the East Coast. The best information was obtained in those regions where mussels are used as fish bait or are considered to compete with soft clams (Mya arenaria) for space on some tidal flats.

SURVEY METHODS

The New Brunswick, Maine, New Hampshire, and some Massachusetts mussel beds were located near the low-tide mark; consequently, examination was relatively simple. Inspection of the bed at low tide was made either by rowing around it in a dory or by walking over it, if conditions permitted. The location, shape, and dimensions of the bed were plotted on a U. S. Coast and Geodetic Survey chart of that region and from such information, the area was determined by planimeter measurements. The variations in mussel sizes and population densities were noted, for these vary considerably on most beds, particularly where the bed extends from several feet below to several feet above the mean low-water mark. One or more samples were taken from what were considered to be characteristic parts of the bed to determine the weights of the meats and the average sizes of the mussles. In some cases, a sample from one square yard of the bed was removed. With this information it was possible to estimate roughly the total number of bushels of marketable mussels on the beds. It was not possible to determine how accurate the estimates were, but is was felt that the error was small and that the quantities were representative of the abundance of the shellfish.

In the Nantucket Island region the mussel beds were not completely exposed at low tide, but were in depths of about one to two fathoms. Here, due to the clearness of the water, most of the beds were easily seen and the examination of the remaining beds was completed by using a boat and a long-handled rake. In the Cape Cod Bay region, the mussels were located by dredging.

All mussel samples were washed free of mud and the dead mussels and shells were separated from the live mussels. The ratio of live mussels to dead mussels and shells was recorded. The live mussels were measured for individual lengths and the ratio of the volume of mussels over two inches in length to those under two inches was ascertained. The meats were removed from those mussels above two inches to obtain the yield per bushel.

LOCATION, AREAS, AND TOTAL CONTENTS OF BEDS

Table 1 presents the data on the locations, areas, and total contents of the mussel beds.

In New Brunswick, the region between Point Lepreau and Saint Andrews was examined during November 1943. Musquash, Beaver, L'Etang, and Bocabec Harbors were not surveyed because information from representatives of the Fisheries Research Board of Canada and the Canadian Department of Fisheries indicated that few mussels were present in those areas. Very limited supplies of mussels were found at

Lepreau Point, Lepreau Harfor, Mill Cove, Midjik Bluff, Digdequash Inlet, Parker, Jameson, and McMaster Islands (Figure 1). This region was examined by Mossop (1921) during 1917 and her observations agree with those of the 1942 survey. The mussels were so small that they were considered to be of no commercial importance. To be commercially important mussels should be at least two inches long and in great enough quantities to make their harvesting profitable.

In the Eastport-Lubec region, which was surveyed during October 1943, mussel beds were not abundant. Jim Island, Spectacle Island, Pennamaquan River near West Pembroke, Scrub Island, and Long Island had small patches of messels. The largest bed was located in Lubec Narrows at Leadurny Point. Less than 26 acres of mussel flats were discovered in the entire Eastport-Lubec section and mussels of over two inches in length were so scarce that the beds were not commercially important.

Information from fishery wardens and fishermen indicated that mussels were not abundant enough to warrant a fishery in the region extending eastward from Jonesboro, Maine, to Lubec, Maine. In order to avoid the expenditure of time on areas offering little prospects of a commercial fishery, the survey was not extended to that region.

Table 1 - Locations, Areas and Estimated Quantities of Mussels on Some Surveyed Beds

Locality	Estimated Bushels Per Acre of Marketable-size Mussels (2" or more in length)	Approximate Area of Bed Containing Marketable Mussels	Total Bushels
	Number	Acres	Number
New Brunswick:			
Lepreau Point	1/	-	-
Lepreau Harbor	1/	-	-
Letite Harbor, Mill Cove	1/	-	-
Little Letite Passage	1/	-	-
Midjik Bluff	300	1	300
Digdequash Inlet	1/	-	-
Total	-	1	300
Maine, Eastport-Lubec Section:			
Moose Island Bridge	1/	-	-
Spectacle Island	1/	-	-
Jim Island	1/	-	-
Leadurny Point	1/	-	-
Long Island	1/	-	-
Scrub Island	1/	-	-
Pennamaquan River	1/	-	-
Total	-	-	-
Maine, Jonesport Section:			
Chandler River	1/	-	-
Mason Bay	1/	-	-
Indian River	15	134	2,010
West River, Goose Islands	75	75	5,625
Cape Split Harbor	600	84	50,400
Pleasant River, Reef Point	70	134	9,380
Harrington River, Ripley Islands	10	28	280
Narraguagus Bay, Back Bay	310	28	8,680
Narraguagus River, Long Point	65	8	520
Pigeon Hill Cove, Bar Island	1/	-	-
Dyer Harbor	1,210	41	49,610
Pinkham Bay	685	44	30,140
Joy Bay	570	44	25,080
Total	-	620	181,725
Maine, Frenchman Bay Section:			
Winter Harbor	500	2	1,000
Steve Island Harbor	380	65	24,700
Hog Island	100	3	300
Seward's Island	75	36	2,700
Ingall's Island	195	10	1,950
Sullivan Harbor, Moon Ledge	145	7	1,015
Raccoon Cove	180	225	40,500
Skillings River	100	10	1,000
Jordan River	1/	-	-
Total	-	358	73,165
Maine, East Penobscot Bay Section:			
Pattens Bay	1/	-	-
Morgans Bay	1/	-	-
Blue Hill Harbor	1/	-	-
Allen's Cove	1/	-	-
Herrick Bay	160	248	39,680
Centre Harbor	335	3	1,005
Deer Isle, Fish Creek	80	129	10,320
Deer Isle, Greenlaw's Cove	75	100	7,500
Deer Isle, Webb Cove	1/	-	-
White Island	500	1	500
Jim's Island	100	1	100
John Island	575	5	2,875
Opechee Island	50	8	400
Swans Island, Mackerel Cove	10	39	390
Swans Island, Atlantic Harbor	40	13	520
Isle au Haut Harbor	375	4	1,500
Total	-	551	64,790
New Hampshire:			
Hampton River	1/	-	-
Massachusetts:			
Duxbury Bay	1/	-	-
Chatham	1/	-	-
Nantucket, Muskeget Island	2	125	250
Nantucket, Maddaket Harbor	600	21	12,600
Total	-	146	12,850

1/ Commercially unimportant because of comparative absence of mussels over two inches in length

The principal mussel areas of eastern Maine were surveyed in October and November 1942, with the exceptions of Pattens Bay, Morgans Bay, and Allen's Cove, which were examined during October 1943. Figures 2, 3, and 4 show the locations of the beds. In the Jonesport area (Jonesboro to Gouldsboro Bay) a total of 620 acres of mussel beds contained about 182,000 bushels of marketable mussels; the

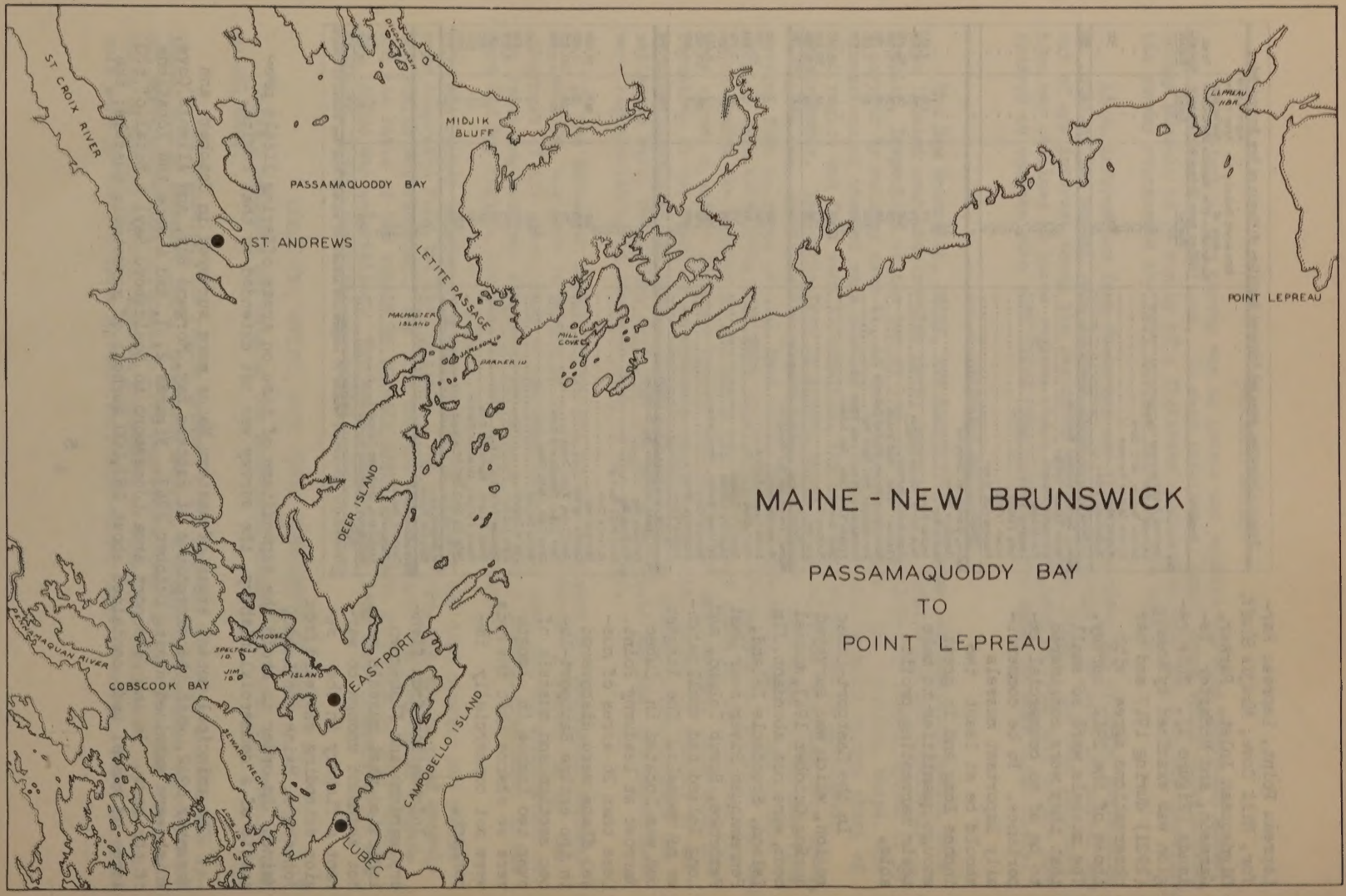

FIGURE 1 - REGIONS SURVEYED BUT IN WHICH MUSSELS WERE NOT FOUND TO BE PRESENT IN COMMERCIALLY IMPORTANT QUANTITIES

Frenchman Bay section had 358 acres of beds and 73,000 bushels of mussels; and the East Penobscot Bay region had 551 acres of beds and about 65,000 bushels.

The survey did not investigate thoroughly the entire coastline even of any one section. The Maine coast has a very large number of islands, rocks, bays, and inlets, many of which offer favorable conditions for the growth of mussels. Most of the beds reported by fishermen, wardens, etc., were examined; however, many small beds were undoubtedly not visited, consequently, the estimated available supplies must be considered as a minimum. Furthermore, the survey of the Jonesport region was more intensive than that of Frenchman Bay, while East Penobscot Bay received the least attention. The reason for this difference was that there was insufficient time to examine the latter two areas as thoroughly as the first; therefore, a comparison of the relative productivity of the three regions cannot be made from the survey. As the fishery developed, the mussel gatherers found many more small beds, particularly in Hancock County.

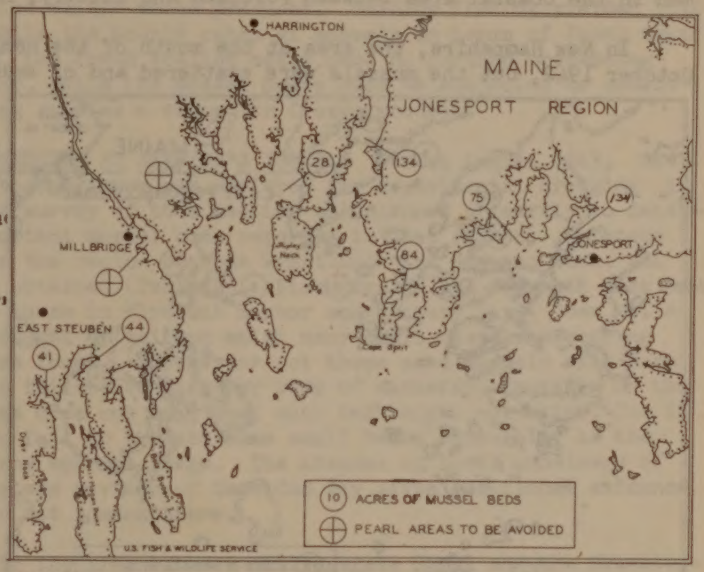

FIGURE 2 - PRINCIPAL MUSSEL BEDS OF THE JONESPORT, ME., REGION.

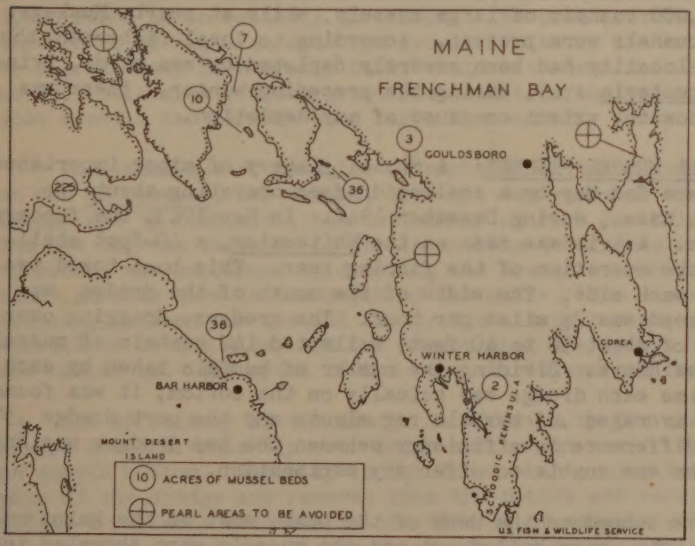

FIGURE 3 - PRINCIPAL MUSSEL BEDS OF THE FRENCHMAN BAY, ME., REGION.

The areas around Mount Desert, Vinalhaven, and North Haven Islands, and West Penobscot Bay, were not surveyed. Wardens of the Maine Department of Sea and Shore Fisheries reported that a good supply of mussels was present around Mount Desert Island; however there was little available information about the other three sections. The remaining sections of the Maine coast between Rockland and Portland were not examined, but fisher-

men who were familiar with both the sizes of the beds and mussels reported large quantities. No beds of commercial importance were reported by wardens or fishermen in the coastal area between Portland and Kittery, Maine.

In New Hampshire, the area at the mouth of the Hampton River was examined in October 1942, but the mussels were scattered and of small size. Fishermen and conservation officers did not believe that a mussel fishery was possible in that State, due to the scarcity of large mussels. The Great Bay area was not surveyed because of lack of any information on possible mussel beds.

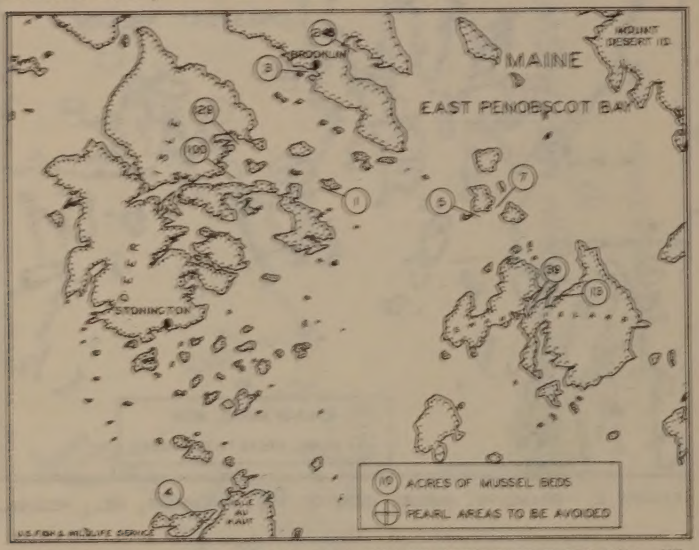

FIGURE 4 - PRINCIPAL MUSSEL BEDS OF THE EAST PENOBSCOT BAY, ME., REGION.

Some regions in Massachusetts also were visited. In December 1942, Plymouth Harbor and Duxbury Bay in Massachusetts were examined. Although there were 36 acres of mussels present in the intertidal zone, the mussels were generally so small that a fishery would be impractical. Chatham Harbor, also examined at this time, contained only mussels under two inches in length. In April 1943, Maddaket Harbor at Nantucket Island contained about 16,000 bushels of large mussels, while at nearby Muskeget Island, an estimated 250 bushels were present. According to local fishermen, the mussel beds at the latter locality had been severely depleted by sea birds, principally the eider duck (Somateria sp.), during the preceding winter. There was no definite evidence to show the extent or cause of any depletion.

OBSERVATION OF A SMALL MUSSEL FISHERY: A mussel fishery of minor importance was being carried on in Cape Cod Bay by a scallop dredger operating about two miles northeast of Dennis, Mass., during December 1942. In May 1943, the fishery was resumed by three boats. A trip was made on the Whitewater, a 40-foot shellfish dredger, to observe the operation of the fishing gear. This boat towed two scallop dredges, one from each side. The width of the mouth of the dredge was seven feet. The towing speed was 2½ miles per hour. The dredges, dragging over a muddy bottom at a depth of about 30 to 40 feet, collected 147 bushels of mussels in slightly less than three hours. Dividing the number of bushels taken by each dredge by the length of time each dredge was actually on the bottom, it was found that the starboard dredge averaged .45 bushels per minute and the port dredge .57 bushels per minute. The difference in efficiency between the two dredges was known to the boat operator but he was unable to offer any explanation.

After the mussels were dumped on the deck of the boat, most of the kelp, rocks, whelks (Buccinum undatum), etc. were culled out and the mussels were shoveled into burlap bags. Examination of the contents of the bags revealed that about 80 percent of the volume was live mussels, the remaining 20 percent being empty shells, rocks, sand dollars (Echinarachinus parma), and other debris.

On the same trip, the Whitewater dredged for scallops and caught 96 pounds of meats in over 5 hours. While the scallop fishing may not have been particularly productive in that region, some comparison can be made between the productivity of the two fisheries in terms of edible meats produced. Scallop fishing yielded 18.8 pounds of meats per hour while the hourly catch of mussels in terms of fresh meats was 645.7 pounds. However, the fresh scallop meats need no further processing before reaching the consumer, while the mussel meats must be subjected to considerable handling before being sold as a canned or frozen product.

EXPERIMENTAL MUSSEL DREDGING BY SERVICE'S VESSEL: During August 1943, the Fish and Wildlife Service boat Skimmer was employed for experimental dredging in the Cape Cod Bay area. The survey of this section was planned primarily to determine the extent of the important mussel beds reported in that region. Thirteen dredging hauls were made in the region between Brant Rock and Scorton Neck, but no marketable mussels were obtained (Table 2). Fishermen in the Plymouth area were unaware of any beds except those in Plymouth Harbor and Duxbury Bay. Tows No. 6 and 7, off Plymouth Bay, brought up kelp on which many small mussels measuring 1/16 to 5/16 of an inch were found. Whether or not these seed mussels will form a bed is questionable. The failure to discover beds of marketable mussels in the Brant Rock-Scorton Neck area does not mean that such beds might not exist, for it would be relatively easy to fail to contact some small beds, especially as the number of dredging operations was not large. The absence of local knowledge of mussel beds in the northwestern portion of Cape Cod Bay gives additional evidence that marketable mussels are not common there.

Mussels were dredged in the area between Billingsgate Shoal and the Brewster-Dennis shores. From the results of the Skimmer's dredge hauls as shown in Table 2, a rough idea may be obtained of the size of this mussel-producing section. The probable center of the mussel bed or beds, is about 2,700 yards southwest of the Billingsgate Shoal buoys, which mark its northern limits, and its southern limit is about 3,300 yards north of the Sesuit Harbor breakwater. Its greatest length is 6,000 yards in a north northeast half east direction and its greatest width 3,600 yards in an easterly direction. The area of this bed has been roughly estimated to be 2,450 acres. The actual limits of the bed are not known exactly, as a great many more dredge hauls would have been necessary to plot the area exactly. This area offered great possibilities in 1943 and, as mentioned before, some mussels had already been taken commercially from the region.

The technique of dredging as employed on the Skimmer varied little from that on the Whitewater; the dredge, however, was somewhat smaller. The mouth of the dredge was 3½ feet wide; the bottom bar or rake bar held 11 one-inch square teeth; and the bag was designed to retain mussels two inches in length. The dredging operation was performed by dropping the dredge overboard and paying out about three times as much wire as the depth of the water. The duration of the tow was the time elapsing between the instant the dredge struck bottom, which was determined by the vibrations in the wire, and the moment when the dredge left the bottom as the wire was hauled in. The speed of the boat was determined frequently by ship logs.

The efficiency of the dredge is affected by the character of the bottom. The dredge bounces violently over rough bottom and has a less marked jumping effect on smooth bottom. Since it is not known what proportion of the mussels in the path of the dredge are removed from the bottom and retained, it is not possible to obtain a reliable estimate of the density of mussels on the beds, unless a considerable number of data are accumulated concerning the efficiency of the dredge. Frey

Table 2.- Record of Mussel Dredging in Cape Cod Bay by the Service's Vessel, "Skimmer"

Tow No.	Date 1943	Position Latitude, N.	Position Longitude, W.	Locality	Depth of Tow Feet	Duration of Tow Minutes	Direction of Tow	Length of Tow Feet	Catch[1/]
1	Aug. 26	41° 58' 51"	70° 35' 0"	Plymouth Bay	44	10	N	2,050	Sand dollars
2	Aug. 27	42° 2' 49"	70° 37' 34"	Off Duxbury Beach	48	13	N ½ E	2,665	do
3	do	42° 3' 14"	70° 38' 9"	do	25	10	N ½ E	2,050	Kelp
4	do	42° 3' 39"	70° 38' 13"	do	34	3	NE by E	2,050	Nothing
5	do	41° 58' 2"	70° 34' 57"	Plymouth Bay	45	10	W by N	2,050	Sand dollars
6	do	41° 59' 3"	70° 35' 35"	do	36	10	S by E	2,050	Sand dollars, kelp, many seed mussels
7	do	41° 59' 25"	70° 35' 36"	do	22	10	SW	2,050	do
8	Aug. 29	41° 47' 51"	70° 30' 21"	Off Sagamore Beach	28	10	SW by S ½ S	2,050	Kelp
9	do	41° 59' 16"	70° 30' 36"	do	29	10	SW by S ½ S	2,050	Sand dollars
10	do	41° 59' 6"	70° 29' 41"	do	40	10	S by W 1/8 W	2,050	do
11	do	41° 48' 29"	70° 28' 32"	do	38	10	E by S ½ S	2,050	2 scallops, sand dollars
12	do	41° 46' 32"	70° 26' 56"	Off Spring Hill Beach	40	10	SE by E ½ E	2,050	1 horse mussel, sand dollars
13	do	41° 45' 1"	70° 23' 52"	Off Scorton Neck	59	10	SE by E ½ E	2,050	Nothing
14	Aug. 30	41° 49' 45"	70° 9' 18"	Brewster to Billingsgate Shoal	42	10	E	2,050	12 quarts mussels
15	do	41° 49' 50"	70° 9' 0"	do	41	10	E	2,050	1 quart mussels
16	do	41° 45' 54"	70° 8' 49"	do	39	10	E	2,050	Kelp
17	Aug. 31	41° 46' 6"	70° 15' 48"	Off Barnstable Bar	47	10	N by E ½ E	2,050	Sand dollars
18	do	41° 45' 58"	70° 16' 12"	do	52	10	N by W ½ N	2,050	do
19	do	41° 46' 47"	70° 16' 8"	do	45	10	S by E ½ E	2,050	do
20	do	41° 45' 33"	70° 15' 49"	do	39	10	W by N ¼ N	2,050	do
21	do	41° 45' 33"	70° 16' 38"	do	39	10	N by E ¼ E	2,050	do
22	do	41° 46' 32"	70° 16' 51"	do	51	10	N by E ¼ E	2,050	2 scallops, whelks
23	do	41° 47' 22"	70° 16' 59"	do	57	10	N by E ¼ E	2,050	7 scallops, sea urchins
24	do	41° 47' 50"	70° 17' 51"	Off Sandy Neck	52	10	W by N ¼ N	2,050	Sand dollars, starfish
25	do	41° 47' 10"	70° 18' 32"	do	53	10	S by W ¼ W	2,050	Sand dollars, sea urchins
26	do	41° 45' 12"	70° 18' 36"	do	54	10	S by W ¼ W	2,050	Sand dollars
27	Sept. 2	41° 45' 42"	70° 11' 22"	Dennis to Billingsgate Shoal	41	10	E	2,050	Kelp
28	do	41° 45' 48"	70° 10' 53"	do	41	10	E	2,050	5 quarts mussels
29	do	41° 46' 53"	70° 10' 23"	do	41	10	E	2,050	Kelp
30	do	41° 46' 58"	70° 9' 57"	do	40	10	E	2,050	do
31	do	41° 45' 14"	70° 11' 12"	do	33	10	E	2,050	1 quart mussels
32	do	41° 45' 15"	70° 10' 42"	do	38	10	E	2,050	1 mussel
33	Sept. 5	41° 47' 5"	70° 9' 34"	do	34	10	N	2,050	32 quarts mussels
34	do	41° 47' 28"	70° 9' 41"	do	34	10	N	2,050	12 quarts mussels
35	do	41° 47' 41"	70° 9' 48"	do	34	10	E	2,050	5 mussels
36	do	41° 47' 45"	70° 9' 22"	do	27	5	E	1,025	Nothing
37	do	41° 47' 48"	70° 9' 12"	do	28	10	E	2,050	12 mussels
38	do	41° 47' 53"	70° 8' 47"	do	28	10	E	2,050	42 quarts mussels
39	do	41° 47' 58"	70° 8' 24"	Brewster to Billingsgate Shoal	27	10	E	2,050	16 quarts mussels
40	do	41° 43' 4"	70° 8' 0"	do	29	10	E	2,050	11 quarts mussels
41	do	41° 48' 9"	70° 7' 36"	do	28	10	E	2,050	Many small mussels
42	do	41° 48' 14"	70° 7' 11"	do	28	10	E	2,050	do
43	do	41° 48' 19"	70° 6' 47"	do	27	10	E	2,050	do
44	do	41° 48' 24"	70° 6' 23"	do	26	10	E	2,050	Kelp
45	do	41° 48' 30"	70° 6' 0"	do	26	10	S	2,050	do
46	do	41° 47' 24"	70° 8' 22"	do	29	10	S	2,050	Nothing
47	do	41° 48' 3"	70° 8' 37"	do	26	10	N	2,050	1 quart mussels
48	do	41° 48' 20"	70° 8' 44"	do	29	10	N	2,050	19 quarts mussels
49	do	41° 48' 38"	70° 8' 52"	do	35	10	N	1,500	42 quarts mussels
50	do	41° 48' 51"	70° 8' 56"	do	36	10	N	1,500	31 quarts mussels
51	do	41° 49' 6"	70° 9' 1"	do	36	10	N	1,500	26 quarts mussels
52	do	41° 49' 19"	70° 9' 5"	do	42	10	N	1,500	2 mussels, 7 horse mussels
53	do	41° 49' 32"	70° 9' 12"	do	46	10	N	1,500	57 quarts mussels
54	Sept. 6	41° 49' 15"	70° 10' 18"	Dennis to Billingsgate Shoal	31	10	S	2,050	Sand dollars
55	do	41° 48' 56"	70° 10' 13"	do	46	10	S	2,050	do
56	do	41° 48' 38"	70° 10' 9"	do	41	10	S	2,050	do
57	do	41° 48' 15"	70° 10' 5"	do	41	10	S	2,050	5 mussels
58	do	41° 47' 57"	70° 9' 57"	do	37	5	S	1,025	Nothing
59	do	41° 47' 44"	70° 9' 54"	do	35	7	S	1,435	1 quart mussels
60	do	41° 47' 25"	70° 9' 51"	do	32	10	S	2,050	2 horse mussels
61	do	41° 46' 59"	70° 9' 43"	do	32	10	S	1,800	2 mussels, 3 horse mussels
62	do	41° 46' 42"	70° 9' 40"	do	32	10	S	1,800	1 horse mussel, many seed mussels
63	do	41° 46' 25"	70° 9' 37"	do	32	10	S	1,800	2 mussels, many seed mussels
64	do	41° 46' 3"	70° 9' 57"	do	28	10	N	2,050	3 horse mussels, many seed mussels
65	do	41° 46' 21"	70° 10' 5"	do	32	10	N	2,050	2 horse mussels
66	do	41° 46' 42"	70° 10' 12"	do	36	10	N	2,050	2 horse mussels
67	do	41° 47' 0"	70° 10' 19"	do	32	10	N	2,050	1 horse mussel
68	do	41° 47' 19"	70° 10' 26"	do	36	10	N	2,050	6 mussels
69	do	41° 47' 38"	70° 10' 32"	do	42	10	N	2,050	4 mussels, 1 horse mussel
70	do	41° 48' 20"	70° 11' 33"	do	46	10	S ¾ W	2,050	Scallops
71	do	41° 48' 2"	70° 11' 31"	do	48	7	N ¾ E	1,435	do
72	do	41° 48' 16"	70° 11' 32"	do	47	7	S ¾ W	1,435	do
73	do	41° 46' 2"	70° 11' 31"	do	47	5	S ¾ W	1,025	do
74	do	41° 47' 35"	70° 11' 30"	do	37	10	S ¾ W	2,050	8 mussels, 3 scallops
75	do	41° 47' 16"	70° 11' 27"	do	40	8	S ¾ W	1,640	3 mussels, 3 scallops
76	do	41° 47' 0"	70° 11' 25"	do	36	10	S ¾ W	2,050	Sand dollars
77	do	41° 46' 42"	70° 11' 24"	do	36	10	S ¾ W	2,050	2 horse mussels

1/ Common and scientific names: Sand dollar (Echinarachnius parma); Sea urchin (Strongylocentrotus drobachiensis); Starfish (Asterias vulgaris and A. forbesii); Whelk (Buccinum undatum); Mussel (Mytilus edulis); Horse mussel (Modiolus modiolus); Scallop (Pecten magellanicus); Kelp - Principally members of the LAMINARIACEAE.

(1946) cites similar difficulties with dredging operations in oyster population studies. In view of such difficulties, no attempt has been made to estimate the abundance of mussels in the Cape Cod Bay area.

PART II - OBSERVATIONS ON THE BIOLOGY AND THE METHODS OF COLLECTING AND PROCESSING THE MUSSEL

INTRODUCTION

This is the second of three papers concerning the World War II efforts to develop a mussel fishery in the North Atlantic region. The first article dealt with the survey to discover whether supplies of mussels were great enough to support a large fishery. The present paper is concerned with biological and technological observations made during the mussel survey.

SIZES OF MUSSELS

Table 3 reveals some interesting characteristics of the size distribution of the mussels on the beds. An examination of the table shows that there are many localities in which there is no well defined and distinct mode indicative of the young from the summer's set. Only Pleasant River, Narraguagus River, Winter Harbor, and Duxbury Bay have such modes. The absence of distinct year-size groups is even more apparent in the areas below low tide at Ingall's Island, Jim's Island, Moon Ledge, Skillings River, Sheep Island, Mackerel Cove, Maddaket Harbor, and off Brewster. In these eight localities, between 92.7 and 100 percent of the mussels were over two inches in length. There is little information available concerning the growth of mussels under natural conditions in the North Atlantic region. Mossop (1921, 1922) states that mussels grew 10.8 mm (.43 inches) per year at St. Andrews, New Brunswick, in the intertidal zone, while on a submerged reef the growth was 14.8 mm (.58 inches). At Sorrento, Maine, in October 1946 the mussel spat averaged .13 inches in length and ranged from .01 to .34 inches.

SOME OF THE MUSSEL'S ENEMIES:
1. A SEA MUSSEL WHICH HAS BEEN PERFORATED BY ONE OF THE WINKLES.
2. THE OYSTER DRILL (UROSALPINX CINEREA).
3. THE DOG WHELK (PURPURA LAPILLUS).
4. THE WINKLE (LUNATIA HEROS).
5. THE STARFISH (ASTERIAS FORBESII) ATTACKING A MUSSEL.
6. THE CONCH (BUSYCON CARICA).

It does not seem possible that lack of small mussels in many of the localities during September, October, and November, can be attributed to rapid growth of the year's spat to the three-or four-inch size. It would seem more likely that the survival of the spat is variable from year to year. Lambert (1935) reported that

the production of spat from the Zeland mussel beds was very irregular from year to year. Mossop (1921) stated that some years are poor spat producers in New Brunswick, and Storrow (1940) cited the disappearance of 1936 spat and the failure of any successful spat formation in 1937 and 1938 at Whitby, England. Hobson, Storrow, Leach, and Wright (1935) reported that the fall of spat at Blyth, England, was unimportant during two or three years prior to 1935, and that this condition was also true at Budle Bay and Holy Island. Observations at Sorrento and Sullivan, Maine, during 1946 revealed that, although no spat had set on the natural beds, a heavy set of spat had occurred on brush which had been put on the flats in hope of encouraging the successful settling of clams. This spat failed to survive the winter except for a negligible portion which set close to the mud. While mussels are reared in the Baltic on harwood branches thrust into the mud, such a method of culture might not be economically feasible in the United States because of labor costs. Possible methods for cultivation of this species are given by Loosanoff (1942, 1943a).

On all ten beds from which mussels were taken both from below and above the low-tide mark, the mussels from below were larger than those from above. (Figure 5 shows this difference in size.) The larger size of the submerged mussels is characteristic of most North Atlantic mussel beds. Studies on the St. Andrews, New Brunswick, mussels by Mossop (1921, 1922), Coulthard (1929), Newcombe (1935), and Warren (1936) demonstrated that the rate of growth varied inversely with the exposure between tides. Another factor, not yet clearly evaluated, is the possibility that there is a decreased mortality among the submerged mussels and they are able to grow to a larger size. No attempt was made during the survey to analyze the growth rate of the mussel populations.

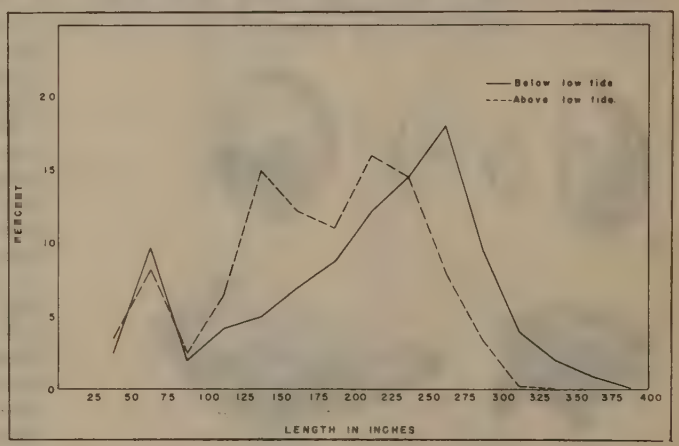

FIGURE 5 - SIZE OF MUSSELS FROM ABOVE AND BELOW LOW TIDE ON TEN MAINE MUSSEL BEDS.

The mussel beds of New Brunswick, Maine, and New Hampshire are situated near the low-tide mark. Very few mussels are found more than three feet below the low-tide level. Huntsman (1918), Mossop (1921), Newcombe (1935), and Warren (1936) remarked on the absence of New Brunswick mussels in depths of over a fathom, and believed that predators, such as, starfish (Asterias vulgaris and A. forbesii), sea urchins (Strongylocentrotus drobachiensis), whelks (Buccinum undatum), cockles (Polinices heros), and drills (Thais lapillus) were responsible. These predators, in general, do not occur in less than a fathom.

In contrast, many beds in Cape Cod Bay, Buzzard's Bay, and other southern New England localities are located in depths of over 40 feet. During dredging operations in Cape Cod Bay, starfish, sea urchins, and whelks (Table 2)[1/] were collected with mussels. This would indicate that either these predators were in such small numbers as not to prevent the establishment of beds in subtidal depths, or perhaps factors other than predators influence the depth at which mussels grow.

1/Appeared in Part I published in September 1949 issue of Commercial Fisheries Review.

Table 3 - Sizes of mussels from Various Areas

Locality	Date	Depth in Relation to Mean Low Water	Dead Mussels by Volume	Live Mussels	Live Mussels by Length Groups															Average size (total)	Average size above 2"	Above 2"	
					0.00 to 0.24	0.25 to 0.49	0.50 to 0.74	0.75 to 0.99	1.00 to 1.24	1.25 to 1.49	1.50 to 1.74	1.75 to 1.99	2.00 to 2.24	2.25 to 2.49	2.50 to 2.74	2.75 to 2.99	3.00 to 3.24	3.25 to 3.49	3.50 to 3.74	3.75 to 3.99	4.00 to 4.24			By Number	By Volume
		Feet	Percent	Number	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Inches	Inches	Percent	Percent
New Brunswick:																									
Lepreau Point	Nov.17,1943	2 to 0	2/	74	-	3	-	11	24	23	7	-	-	1	2	2	-	1	-	-	-	1.31	2.78	8.1	2/
Lepreau Harbor	do	2 to 0	2/	101	-	-	1	22	38	36	5	-	-	-	-	-	-	-	-	-	-	1.16	-	0.0	0.0
Letite Harbor, Mill Cove	Nov.16,1943	2 to -1	2/	114	-	-	-	1	6	49	50	8	-	-	-	-	-	-	-	-	-	1.48	-	0.0	0.0
Little Letite Passage	do	2 to -1	2/	166	-	-	-	5	19	42	58	35	6	1	-	-	-	-	-	-	-	1.56	2.11	4.2	2/
Midjik Bluff	Nov.19,1943	2 to 0	50.0	134	-	-	-	-	1	9	15	[illegible]	46	12	3	-	-	-	-	-	-	1.95	2.17	45.5	62.5
do	do	4 to 2	2/	62	-	1	-	1	9	28	19	2	2	-	-	-	-	-	-	-	-	1.43	2.06	3.2	2/
Digdequash Inlet	Nov.18,1943	2 to 0	2/	180	-	-	14	28	35	28	15	2	-	-	-	-	-	-	-	-	-	1.14	-	0.0	0.0
Maine, Eastport-Lubec Section:																									
Spectacle Island	Oct.12,1943	2 to 0	2/	91	-	-	-	-	3	15	30	21	2	-	-	-	-	-	-	-	-	1.65	2.09	2.2	2/
Jim Island	do	2 to 0	2/	60	-	-	1	1	28	26	4	-	-	-	-	-	-	-	-	-	-	1.24	-	0.0	0.0
Leadurny Point	Nov.30,1943	1 to 0	2/	125	-	1	7	13	34	24	33	12	-	1	-	-	-	-	-	-	-	1.07	2.02	.8	2/
Long Island	Oct.11,1943	2 to 0	2/	124	-	-	-	-	-	4	7	61	36	14	-	2	-	-	-	-	-	1.99	2.20	41.9	2/
Scrub Island	Oct.14,1943	2 to 0	2/	199	-	-	6	9	5	13	73	70	20	2	-	1	-	-	-	-	-	1.69	2.15	11.6	2/
Pennamaquan River	Oct.15,1943	2 to 0	2/	164	-	-	-	1	10	15	71	63	4	-	-	-	-	-	-	-	-	1.68	2.14	2.4	2/
Maine, Jonesport Section:																									
Indian River	Oct.20,1942	3 to -2	2/	127	-	1	-	1	1	1	3	18	25	32	22	10	9	3	-	-	-	2.33	2.83	78.7	2/
do	do	2 to 0	36.0	122	-	1	1	3	18	30	14	29	22	3	2	-	-	-	-	-	-	1.63	2.16	21.3	2/
West River	do	0 to -2	18.5	198	-	-	-	4	15	33	18	32	61	25	7	2	1	-	-	-	-	1.88	2.24	46.5	77.0
Cape Split Harbor	Oct.21,1942	0 to -2	18.5	87	-	-	-	-	1	2	2	8	10	15	20	17	10	2	-	-	-	2.56	2.66	85.1	93.8
do	do	2 to 0	18.5	191	-	-	-	2	6	4	22	25	27	43	36	18	7	-	-	-	-	1.97	2.36	54.5	78.9
Pleasant River, Reef Point	Oct.23,1942	0 to -2	33.1	227	-	16	88	8	6	21	28	27	18	6	7	2	-	-	-	-	-	1.27	2.36	14.5	45.7
do	do	2 to 0	28.7	284	-	33	108	6	3	14	19	18	14	8	9	1	-	-	-	-	-	1.03	2.32	12.5	58.5
Harrington River, Ripley Is.	Oct.30,1942	0 to -2	13.6	161	-	8	17	5	17	6	23	26	34	19	6	-	-	-	-	-	-	1.76	2.29	36.6	65.7
do	do	2 to 0	20.5	116	-	-	2	8	21	44	26	14	2	-	-	-	-	-	-	-	-	1.40	2.11	1.7	8.2
Narraguagus Bay, Back Bay	Oct.31,1942	0 to -2	31.8	169	-	-	7	17	25	44	41	23	8	5	1	-	-	-	-	-	-	1.51	2.17	14.1	33.8
do	Long Point	1 to -2	31.8	193	-	5	92	25	21	34	17	12	5	-	-	2	-	-	-	-	-	.81	2.53	1.0	12.5
Pinkham Cove	Nov. 2,1942	2 to -2	17.0	153	-	5	6	10	9	10	14	29	39	18	12	1	-	-	-	-	-	1.78	2.25	45.9	69.1
Joy Bay	Nov. 3,1942	2 to -2	25.0	162	-	3	15	15	11	12	30	25	27	9	7	5	-	-	-	-	-	1.64	2.30	29.6	59.1
Maine, Frenchman Bay Section:																									
Winter Harbor	Nov. 5,1942	2 to -2	30.9	190	17	68	47	14	8	8	9	8	3	4	2	4	4	1	-	-	-	.82	2.69	9.5	73.2
Steve Island Harbor	do	0 to -2	15.7	177	-	2	4	4	11	24	20	17	26	33	21	8	6	-	-	-	-	1.98	2.46	53.7	82.7
do	do	2 to 0	22.0	212	-	14	5	3	32	40	19	8	12	40	19	-	-	-	-	-	-	1.62	2.39	33.5	78.1
Hog Island	Nov.10,1942	2 to -2	24.1	157	-	2	5	7	12	18	14	14	13	13	14	18	6	1	-	-	-	1.98	2.60	47.4	84.8
Seward's Island	Nov.11,1942	0 to -2	22.6	109	-	-	1	2	1	2	10	16	18	29	11	12	4	2	1	-	-	2.26	2.51	70.6	87.5
Ingall's Island	Nov. 7,1942	0 to -2	25.4	47	-	-	-	-	1	-	-	-	1	-	4	5	9	17	9	1	-	3.18	3.23	99.9	99.8
do	do	2 to 0	4.6	144	-	10	15	8	19	36	18	4	14	18	8	1	-	-	-	-	-	1.47	2.33	85.0	98.1
Sullivan Harbor, Moon Ledge	Nov. 6,1942	0 to -2	9.5	72	-	-	-	-	-	-	-	-	11	20	24	13	3	1	-	-	-	2.56	2.56	100.0	100.0
do	do	2 to 0	27.4	74	-	-	-	-	1	9	18	14	7	18	5	2	-	-	-	-	-	1.98	2.42	43.2	78.0
Raccoon Cove	Nov. 8,1942	2 to -2	10.2	110	-	-	1	1	2	6	8	10	25	14	24	13	6	-	-	-	-	2.08	2.51	74.5	90.7
Skillings River	do	0 to -2	24.5	89	-	-	-	-	-	-	1	-	5	12	31	9	4	-	-	-	-	2.51	2.98	87.6	99.1
Maine, East Penobscot Bay Sec.:																									
Herrick Bay	Nov.18,1942	2 to -2	12.7	123	-	-	2	3	5	12	12	9	13	20	22	12	11	2	-	-	-	2.21	2.61	65.0	94.1
Centre Harbor	Nov.15,1942	2 to -2	12.0	122	-	-	1	1	3	2	5	28	34	23	9	4	5	2	-	-	-	2.16	2.38	67.2	91.4
Deer Isle, Pisn Creek	Nov.17,1942	2 to -2	25.5	164	-	1	5	8	18	17	25	18	16	19	27	11	1	1	-	-	-	1.91	2.49	45.7	84.4
Deer Isle, Greenlaw's Cove	do	2 to -2	26.7	45	-	-	1	1	-	2	3	4	6	9	10	6	4	1	-	-	-	2.34	2.61	75.5	91.7
White Island	do	2 to -2	30.8	80	-	-	-	-	1	1	1	1	6	4	11	19	22	8	5	1	-	2.61	2.74	87.5	97.1
Jim's Island	do	2 to -2	31.4	69	-	-	-	-	-	-	-	-	8	5	34	19	5	1	-	-	-	2.44	2.47	92.7	95.1
Swan's Island, Mackerel Cove	Nov.23,1942	0 to -2	31.2	28	-	-	-	-	-	-	-	-	-	1	7	24	30	7	-	-	-	2.75	2.75	100.0	100.0
do	do	2 to 0	7.6	134	-	-	1	-	8	10	32	27	37	15	6	-	-	-	-	-	-	1.92	2.23	43.3	88.7
do	Atlantic Harbor	0 to -2	23.6	96	-	-	1	8	1	1	-	4	12	15	45	11	-	1	-	-	-	2.40	2.57	87.5	95.7
do	do	2 to 0	10.0	276	-	2	6	7	3	27	37	33	38	48	70	32	8	1	-	-	-	2.12	2.49	61.8	90.4
Maine, East Penobscot Bay Sec.:																									
Muscle Ridge Channel, Sheep Is.	Nov.20,1942	0 to -2	36.6	79	-	-	-	-	1	-	2	1	2	17	36	14	4	-	-	-	-	2.39	2.63	94.8	97.4
do	do	2 to 0	21.0	160	-	-	-	-	-	-	3	11	29	66	5	-	-	-	-	-	-	1.96	2.35	93.8	94.0
Massachusetts:																									
Duxbury Bay	Dec.16,1942	1 to -1	20.0	452	124	40	99	31	17	21	26	45	29	2	-	-	-	-	-	-	-	.82	2.11	6.9	34.3
Chatham Harbor	Dec.18,1942	1 to 0	2/	175	-	-	3	16	43	101	11	1	-	-	-	-	-	-	-	-	-	1.26	-	0.0	0.0
Cape Cod Bay, off Brewster	do	-25 to -40	25.0	149	-	-	-	-	-	-	-	-	1	4	10	47	36	14	14	3	-	3.04	3.04	100.0	100.0
do	Sept.5,1944	-25 to -40	25.0	53	-	-	-	-	-	-	-	-	-	-	1	2	4	22	17	7	-	3.47	3.47	100.0	100.0
Muddaket Harbor	Mar.21,1943	-1 to -2	2/	57	-	-	-	-	-	-	-	-	-	-	3	9	23	17	4	-	1	3.18	3.18	100.0	100.0

1/Calculated from original ungrouped measurements. 2/Not recorded.

The upper limits of the beds are determined by the effect of exposure on young mussel larvae, according to Mossop (1921). Undoubtedly, the larger mussels also suffer considerable mortality from exposure to temperature extremes and to the erosion of ice or storms. Crows, gulls, and ducks may also be important factors in some regions.

MEAT YIELDS

The seasonal variation in the yield of mussel meats is of great importance, both to those engaged in processing mussels and to the conservationists. To harvest the shellfish at the peak of their "fatness" is a sound practice, for the processor is able to obtain a greater poundage of meats from a bushel, thus reducing the cost of the meats; the cannery workers operate at greater efficiency by producing more meat weight from the effort expended to shuck out a bushel; and the harvesting of the mussel at its peak provides the maximum production from a given quantity of mussels.

Table 4 - Pounds of Raw Mussel Meats per Bushel at Various Localities

Locality	Date	Quantity of Meat per Bushel, Depth in Feet in Relation to Mean Low-water: 2 to 0	0 to -2	2 to -2	-25 to -40
		Pounds	Pounds	Pounds	Pounds
Maine, Jonesport Section:					
Indian River	Oct. 20, 1942	-	10.9	-	-
West River	do	9.6	-	-	-
Cape Split Harbor	Oct. 21, 1942	14.4	14.8	-	-
Pleasant River, Reef Point	Oct. 23, 1942	12.7	14.8	-	-
Harrington River, Ripley Is.	Oct. 30, 1942	-	13.1	-	-
Narraguagus River, Back Bay	Oct. 31, 1942	-	-	12.2	-
Pinkham Cove	Nov. 2, 1942	-	-	11.4	-
Joy Bay	Nov. 3, 1942	-	-	12.2	-
Average		12.2	13.4	11.9	-
Maine, East Penobscot Bay Sec.:					
Winter Harbor	Nov. 5, 1942	-	-	19.4	-
Stave Island Harbor	do	12.3	14.8	-	-
Hog Island	Nov. 10, 1942	-	-	12.7	-
Soward's Island	Nov. 11, 1942	-	13.6	-	-
Ingall's Island	Nov. 7, 1942	14.4	16.9	-	-
Sullivan Harbor, Moon Ledge	Nov. 6, 1942	8.4	13.1	-	-
Raccoon Cove	Nov. 8, 1942	-	-	11.9	-
Skillings River	do	-	12.7	-	-
Bar Harbor	Nov. 9, 1942	-	-	14.8	-
Average		11.7	14.2	14.7	-
Maine, E. Penobscot Bay Sec.:					
Herrick Bay	Nov. 18, 1942	-	-	16.9	-
Centre Harbor	Nov. 15, 1942	-	18.6	-	-
Deer Isle, Fish Creek	Nov. 17, 1942	-	-	17.4	-
Deer Isle, Greenlaw's Cove	do	-	-	16.1	-
White Island	do	-	-	19.7	-
Jim's Island	do	-	-	21.1	-
Swan's Island, Mackerel Cove	Nov. 23, 1942	13.1	14.4	-	-
Swan's Island, Atlantic Harbor	do	13.1	16.9	-	-
Average		13.1	16.6	18.2	-
Maine, W. Penobscot Bay Sec.:					
Muscle Ridge Channel, Sheep Island	Nov. 20, 1942	12.2	15.2	-	-
Massachusetts:					
Cape Cod Bay, off Brewster	May 12, 1943	-	-	-	16.1

A difference in the meat yields between the Jonesport, Frenchman Bay and East Penobscot Bay regions can be noted from Table 4. It is evident that the East Penobscot Bay mussels were fatter than those of the other two regions, and the Jonesport section mussels had the poorest meats. However, to separate the effect of season and location, samples would have to be taken throughout the year in various sections of the coast. It is interesting to note that when the Maine fishery developed after 1942, the canners preferred the mussels collected from beds in Frenchman Bay and Penobscot Bay due to the heavy yield of meats in those sections as compared with the Washington County region.

In all eight areas where meat weights were obtained from mussels gathered from above and below low tide, the mussels below low tide had heavier meats. The greater meat yields of the submerged mussels and their larger size were the primary reasons why many Maine canneries insisted that the fishermen collect mussels from below the intertidal zone.

To determine the seasonal variation of mussel yields, two localities in Boothbay Harbor, Maine, were selected as sampling stations. Station A was located two feet above the mean low-water mark and Station B was at the mean low-water mark. Due to unusual ice conditions and the loss of the mussels by freezing, Station B had to be abandoned in December. Table 5 shows the yield of fresh mussel meats between October 1943 and August 1944. From these data it is apparent that Boothbay Harbor mussels reach their peak condition in June and gain relatively little weight during August through February.

Table 5 - Yield of Fresh Mussel Meats at Boothbay Harbor, Maine

Date	Quantity of Meats per Bushel	
	Station A	Station B 1/
1943:	Pounds	Pounds
Oct. 8	11.0	11.8
18	-	13.6
20	12.2	-
25	13.5	14.3
Nov. 1	11.3	-
2	-	13.2
7	11.9	-
25	12.3	12.8
Dec. 2	-	13.2
3	11.8	-
20	11.2	-
1944:		
Feb. 22	12.5	-
Apr. 4	15.4	-
May 7	17.5	-
June 4	19.3	-
July 8	11.4	-
Aug. 2	11.7	-

1/ Mussels destroyed at Station B by freezing during December.

The weekly yield of steamed meats at a Maine cannery is shown in Table 6. The mussels had been steamed 12 minutes at 212 degrees Fahrenheit before being opened. The shellfish were collected during the 1943-44 season from the same region in Muscongus Bay; therefore, the yields can be considered as representative of that particular locality. During the period December 11 to January 22 the yields tended to decrease; but thereafter began to increase to the end of the season on May 6, when the cannery began experiencing difficulties in handling the meats, which have a tendency to break apart when the spawn is fully developed.

To compare the fresh-shucked yields with those of steamed mussels, it is necessary to apply a conversion factor of 0.5 to the fresh weights. This factor is a rough approximation, for the yield of steamed mussels is inversely affected by the temperature and duration of the steaming process, both of which shrink the fresh meats.

MUSSEL PEARLS

White or bluish white pearls are commonly found in mussel meats. These pearls are valueless, for their small sizes, lack of lustre, and irregular shapes preclude their use in jewelry. As these pearls are usually very small, they are not general-

ly noticed by the consumer to any greater extent than he would notice occasional grains of sand in clams or oysters. However, if the pearls are over one millimeter in diameter and very numerous, they are not only annoying, but may cause damage to the consumer's teeth. On rare occasions, pearls have been found which measure more than six millimeters in diameter; fortunately, most pearls are less than one millimeter in diameter. The presence of large and numerous pearls might prove to be a deterrent to the sale of mussels; consequently, a method of eliminating this nuisance was sought.

Table 6 - Yield of Meats per Bushel of Steamed Mussels at a Maine Cannery during 1943-44 Season

Week Ending	Operating Days	Bushels Processed	Total Meat Yield	Meat Yield per Bushel
1943:	Number	Number	Pounds	Pounds
Dec. 4	4	460.0	2,700.3	5.87
11	6	764.5	4,800.7	6.28
18	5	456.0	2,802.2	6.15
25	4	480.0	2,828.4	5.89
1944:				
Jan. 1	4	464.0	2,830.6	6.10
8	3	403.0	2,321.8	5.76
15	5	540.0	3,213.9	5.95
22	5	551.0	3,221.3	5.85
29	5	549.0	3,497.8	6.37
Feb. 5	4	588.0	3,883.7	6.60
12	5	614.5	4,136.1	6.73
19	3	374.0	2,468.8	6.60
26	6	893.0	6,433.0	7.20
Mar. 4	6	766.0	5,552.3	7.25
11	6	800.0	6,022.2	7.53
18	5	809.0	6,176.6	7.63
25	5	690.0	5,211.5	7.55
Apr. 1	6	826.0	6,566.9	7.95
8	5	865.0	7,395.9	8.55
15	5	684.0	5,970.6	8.73
22	5	712.0	6,425.6	9.02
29	5	704.0	6,279.0	8.92
May 6	1	120.0	1,122.6	9.36
Total	108	14,113.0	101,861.8	7.22

The pearls are embedded in the flesh of the mantle and cannot be seen easily when the gonads are approaching maturity in the winter and spring. No practical method has been developed to detect all the pearls in the meats or to separate mechanically the pearls from the mantle without tearing the latter to shreds. Often it is possible to discover excessively pearly mussels as they are being removed from the shells, or while they are being weighed into the cans, and such meats should be discarded. Several of the canneries have workers detailed to remove all conspicuously pearly meats. The rejection of such meats is only a partial solution to the problem because many of the embedded pearls would not be seen.

During the survey, the quantities of pearls present in mussels collected from various beds were determined by a simple laboratory method of maceration. Three ounces of fresh meats were placed in a quart of boiling water and one ounce of potassium hydroxide was added. The solution was then boiled for five minutes. When the meats became thoroughly macerated, the pearls dropped to the bottom of the container from which they could be easily removed. With one exception, no attempt was made in the field to remove the tiny pearls of less than about .25 millimeters from the mixture of sand and debris, for such pearls were so small that their presence would hardly be detected by the consumer. In a later experiment, to evaluate the effect of acetic acid on pearls, all pearls visible under a low power microscope were measured.

Table 7 shows the numbers and sizes of pearls from each three-ounce sample of meats taken from the various beds. Although all areas contained pearls to a greater or lesser extent, the occurrence of the larger and most objectionable ones was limited. At the end of the Maine survey in 1942, it was felt that, until further study was made, mussels should not be taken from those beds whose samples showed the greatest numbers of large pearls. It was decided to consider as beds to be temporarily avoided those areas whose samples had either more than nine pearls with

a diameter of one millimeter and greater, or more than three pearls with a 1.5 millimeter diameter and greater in a three-ounce sample of fresh drained meats. By use of such standards, about one-fifth of the total estimated mussel production would be eliminated, but this quantity would not seriously interfere with the potential fishery. The areas which would thus be banned temporarily from the mussel supply were: Back Bay, Skillings River, Ripley Islands, Long Point, State Island, and Joy Bay, which had a total estimated supply of 60,000 bushels. Canners were advised in January 1943 to avoid these areas until a further study was made.

Table 7 - Number of Pearls from Commercially Important Mussel Beds[1/]

Location of Bed	Diameter of Pearls in Millimeters Along Longest Axis										
	Quantity								Summary		
	0.25 to 0.99	1.00 to 1.24	1.25 to 1.49	1.50 to 1.74	1.75 to 1.99	2.00 to 2.24	2.25 to 2.49	2.50 to 2.74	1 mm and over	1.50 mm and over	1.75 mm and over
Maine:	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
Mackerel Cove	17	-	-	-	-	-	-	-	-	-	-
Pemaquid River	7	1	-	-	-	-	-	-	1	-	-
Centre Harbor	18	1	-	-	-	-	-	-	1	-	-
Hog Island	3	-	1	-	-	-	-	-	1	-	-
Herrick Bay	4	-	-	1	-	-	-	-	1	1	-
Winter Harbor	6	-	-	1	-	-	-	-	1	1	-
White Island	13	2	-	-	-	-	-	-	2	-	-
Pinkham Bay[2/]	10	1	-	1	-	-	-	-	2	1	-
Cape Split Harbor	1	-	1	-	1	-	-	-	2	1	1
Fish Creek	10	-	1	-	1	-	-	-	2	1	1
Jim's Island	3	1	1	-	1	-	-	-	3	1	1
Moon Ledge	13	1	-	2	-	-	-	-	3	2	-
Raccoon Cove	4	3	1	-	-	-	-	-	4	-	-
Goose Islands	5	3	1	-	-	-	-	-	4	-	-
Indian River	5	4	-	1	-	-	-	-	5	1	-
Ingall's Island	4	4	-	-	-	1	-	-	5	1	1
Greenlaw's Cove	5	-	2	3	-	-	-	-	5	3	-
Sheep Island	12	2	-	3	-	-	-	-	5	3	-
Reef Point	8	5	1	2	-	1	-	-	9	3	1
Soward's Island	19	4	2	1	1	-	-	1	9	3	2
Back Bay	18	1	2	4	-	2	-	-	9	6	2
Skillings River	17	5	2	4	-	1	-	-	12	5	1
Ripley Islands	49	9	6	2	-	-	-	-	17	2	1
Long Point	112	11	3	7	-	-	-	-	21	7	-
Stave Island	53	10	4	6	2	-	-	-	22	8	2
Joy Bay	78	12	4	7	1	5	-	-	29	13	6
Massachusetts:											
Cape Cod Bay off Brewster	18	3	-	-	-	-	-	-	3	-	-

1/Number of pearls from 3 ounces of mussel meats. Meats were obtained from mixed samples of mussels collected from parts of each bed.
2/Includes Dyer Harbor.

It was realized that the problem of eliminating the pearls from the meats would be more easily solved if it were possible to dissolve the pearls in the meats without seriously altering the flavor or texture of the meats. Examination of canned vinegar-preserved mussels had revealed that pearls were absent from the meats, although the mussels had been taken from the Narraguagus River area where pearls are common and often large. It appeared that acetic acid might be a pearl-dissolving agent.

In 1943, shortly after the Maine survey was completed, we performed an experiment to determine the effect of acetic acid on pearls. A similar experiment

was effected by the U. S. Food and Drug Administration shortly thereafter. Eight No. 1 picnic cans were each filled with six ounces of meats from steamed Cape Cod Bay mussels. Four different 3-percent salt solutions were prepared--with 1 percent, ½ percent, ¼ percent, and 0 percent acetic acid concentrations. Two cans of meats were filled with each of these solutions, sealed, processed for 30 minutes at 240° F., and opened 10 days later. The flavor of the meats from those cans containing 1-percent and ½-percent acetic acid was slightly sour, but not unpleasantly so. The pearls were then removed from the mussels in each can by the potassium hydroxide maceration method and measured with a stage micrometer on a low-power microscope.

Table 8 shows the results of this experiment. Each can contained six ounces of steamed meats and, as the shrinkage of fresh meats under the steaming process

Table 8 - Effect of Acetic Acid on Mussel Pearls

Number of Cans	Solution	Diameter of Pearls Measured in Millimeters Along Longest Axis								
		Below .50	.50 to .99	1.00 to 1.49	1.50 to 1.99	2.00 to 2.49	2.50 to 2.99	3.00 to 3.49	3.50 to 3.99	Total
		No.	No.	No.	No.	No.	No.	No.	No.	No.
1	3% salt and 1% acetic acid	4	1	-	-	-	-	-	-	5
1	do	5	3							8
Total 2		9	4	-	-	-	-	-	-	13
1	3% salt and ½% acetic acid	23	22	5	1	-	-	-	-	51
1	do	13	6	-	1	1	-	-	-	21
Total 2		36	28	5	2	1	-	-	-	72
1	3% salt and ¼% acetic acid	158	31	2	3	-	-	-	-	194
1	do	85	29	9	-	2	-	-	-	125
Total 2		243	60	11	3	2	-	-	-	319
1	3% salt and no acetic acid	507	55	9	-	1	1	-	-	573
1	do	775	37	4	1	2	-	-	1	820
Total 2		1,282	92	13	1	3	1		1	1,393

in this instance was about 50 percent, each can had the equivalent of 12 ounces of fresh meats, or four times as much as the samples shown in Table 7. The dissolving effect of the acid on pearls is clearly indicated. While the acid-treated pearls were being measured, it was noticed that the acid had completely softened the small pearls, which would crumble when touched, and had dissolved the outer layers of the large pearls so that they were considerably reduced in size. The effect of time on the dissolving action of the acetic acid was not shown by this single experiment. It is probable that a longer storage period would have reduced further the number of pearls.

After further investigation of this problem, the U. S. Pure Food and Drug Administration advised the canners that a certain concentration of acetic acid should be added to the canned mussels. Some canneries began using vinegar and continue to do so, while others depend upon the ability of their help to see and reject pearly meats.

Although there are a number of possible explanations for the presence of pearls in mussels, they are believed generally to be the result of a parasite. Jameson (1902) believed that most mussel pearls result from the encystment of an immature trematode worm and the subsequent deposition of pearly matter around the worm. Herdman (1904), also studying the pearls of English Mytilus edulis, found pearls very

common at Piel and likewise believed that the distomid trematode larva, Distomum somateriae, is largely responsible for the pearls. Stafford (1912) stated that pearls in considerable numbers can be found in Mytilus edulis on the Gaspe coast of Canada, and larvae similar to Distomum somateriae are found in the mussel. The adult form of the worm inhabits the intestines of the eider duck and the scoter duck (Oidemia sp.) both of which are common on the New England coast. No attempt was made during this mussel survey to ascertain the origin and study the formation of pearls in the New England mussels.

GEAR

The equipment used in harvesting mussels varies with the nature of the beds. In New Brunswick and Maine most of the mussels are exposed at extreme low tides; however, the edges of the beds are usually under several feet of water at mean low water. The submerged mussels are gathered easily by use of a long-handled clam hoe or manure fork, and this gear is also used to collect the exposed mussels. In some instances mussels have been picked from the beds by hand, but this method does not permit the collecting of many mussels during the low-tide interval.

One of the most useful tools for mussel fishing is the quahog rake. This implement is about the size of an ordinary garden rake and has teeth three inches long. A wire basket with a capacity of about eight quarts is attached behind the teeth and holds the mussels which are raked from the bottom. Using this rake from a boat, it is possible to gather mussels easily from depths of one to four feet of water. If the fisherman is skillful, shellfish from depths of over ten feet can be harvested in this way. A long-handled clam hoe or manure fork can be used in a similar fashion but, as solitary mussels usually fall off the teeth, it has the disadvantage of not being efficient, except in areas where the mussels are clustered and attached to each other. As the quahog rake has a wire basket, the mussels can be washed free of mud and some shells, by vigorously agitating the basket in the water before the mussels are dumped into the boat. It is impossible to wash the mussels in such a fashion when the clam hoe or manure fork is employed. Due to wartime conditions, quahog rakes were not available to fishermen, so this gear has not been used in the Maine fishery.

Tongs can also be employed for gathering submerged mussels, but this method is quite slow. During the survey, tongs were sometimes used, but were found to be inefficient on mud bottoms where mussels usually live. Great difficulty was experienced in trying to remove from the tongs the mud and shells which were usually mixed with the live mussels.

In Cape Cod, Buzzards and Narragansett Bays, and in Long Island Sound, mussels of marketable size are found in deep-water beds and require the use of an oyster or scallop dredge, altered to retain mussels of two inches or more in length. Such a dredge will not be an especially efficient gear for releasing small mussels after they have entered the dredge, for many mussels are found in clusters, rather than as solitary individuals. Dredges are now sometimes used in Maine in localities where this gear can be operated over the beds at high water. On those bottoms where the mussels are too thinly distributed to be profitably harvested by hoes, forks, or rakes, the dredge can be operated to good advantage; thus it permits a more thorough reduction of the marketable mussel population. What effect the dredge has on the future productivity of the bottom is not known.

Because of the simple gear by which mussels can be harvested, there was no shortage of mussel-fishing equipment. Neither was there an urgent need for new

boats, as the dories, skiffs, and small power boats engaged in lobstering, clamming, and dredging were generally suitable. The only innovation was the use of small flat bottom shallow draft scows to transport mussels from the beds to the shore. In the Frenchman Bay area, where the mussel fishery was prosecuted actively, such scows were commonly employed.

CANNING FACILITIES

During the 1942 survey it was found that there were sufficient canning facilities to pack millions of pounds of mussels annually. Twenty potential Maine mussel factories were located in the region between Jonesboro and Friendship. Of ten cannery operators contacted personally, nine were very much interested in processing mussels. At five canneries it was possible to can sample packs of mussels in 1942. The large sardine factories at Eastport and Lubec were unfortunately without a convenient supply of mussels, for no large quantities were found in that region and adjacent New Brunswick by the survey. In Massachusetts, several Boston and Gloucester canneries indicated their interest in mussels and sample packs also were made there.

THE CHARACTERISTIC POSITION OF LIVE SEA MUSSELS. THE ANTERIOR END BURIED IN THE SAND OR MUD AND THE POSTERIOR OR SIPHON END PROJECTING WELL ABOVE THE LEVEL OF THE BOTTOM.

There was little or no seasonal conflict between the canning of mussels and other types of processed foods. The peak months of fish and vegetable canning are in the summer and fall seasons during which period mussel meats are relatively thin and, therefore, less valuable for canning. Clams are packed during the winter and spring months, but the supply of clams available for canning was only sufficient to enable nine out of twelve clam canneries to operate in 1942 and those nine had been at only 15 to 20 percent capacity for several years prior to 1942. The decrease in clam canning was due to the increased marketing of freshly-shucked clam meats, and to a shortage of both clams and diggers.

The equipment necessary for canning mussels differs little from that employed in clam canning. The same retorts, sealing machinery, and meat-washing devices are used. Any fish cannery having sealing machinery for "round" cans would be able to pack mussels also. All mussels should be washed in a cylindrical revolving drum, and this apparatus was soon adopted by those canneries handling mussels on a large scale. Thus, conversion to mussel canning was relatively simple.

LABOR SUPPLY

In 1942 there was a fairly adequate supply of female labor for mussel canning, especially during the winter when other fish processing was at a minimum. Male labor was not plentiful, but it was felt that the canneries would be able to secure enough men if they could operate on a larger scale during the season of relative inactivity. It was hoped that the mussel fishery would not only provide an additional supply of protein food, but also supply employment for cannery help during the slack season. This hope was realized as the fishery developed and the maintenance of experienced cannery crews was aided by providing them with more regular work.

In Maine, the clam diggers in the regions where mussels were abundant have been able to increase their production of food per man by gathering both mussels and clams. Some lobstermen were also mussel harvesters and prosecuted the mussel fishery during the late winter and early spring months when the returns from lobster fishing were low. In Massachusetts, where the mussels were found in deeper water, the scallop, quahog and sea clam fishermen were able to dredge mussels with little change in equipment. In all instances, there was an increase in the food production per man when the fishermen shifted from other shellfish harvesting to mussels.

PROCESSING

There are three forms in which mussels can be marketed:

1. Fresh, in the shell or shucked
2. Quick frozen
3. Canned

Mussels also can be demyarted, but whether or not they would be acceptable to the public in this form is questionable. One disadvantage of marketing fresh mussels is apparent--it would have to be limited to population centers not far distant from the source of the shellfish, for mussels do not keep well except under special conditions. It was felt that during the period when mussels were being introduced to a greater segment of the public, it would be likely that gluts would occur, and spoilage might have resultant bad effects on future sales.

Little study has been carried on concerning the possibility of marketing quick-frozen mussels. The effect of long periods of storage on the flavor, appearance, and nutritive values of frozen mussels is not known certainly, although samples of mussels frozen for four months have been rather disappointing due to a slightly bitter taste, dark color, and toughened texture. Until further technological studies of this problem have been conducted, North Atlantic mussels probably will continue to be marketed primarily as a canned product.

The marketing of canned mussels resulted in an almost unlimited range of distribution, with little if any opportunity for spoilage. During the course of the survey, samples of mussels were shipped to a number of canners who were interested in the possibilities of mussel canning and experimental packs were prepared. The following methods were found to be most satisfactory in the experimental work, and were adopted by most of the mussel canners when the fishery later developed.

At the cannery, the mussels were washed in an apparatus similar to the cylindrical fish scaler used for redfish, herring, alewives, etc. The agitation of the mussels, together with the force of the streams of water directed upon them, caused

any mud-filled shells to open and the mud to be washed out. The mud-filled shells are difficult to detect otherwise, and, if not removed, will either break apart during steaming or at the shucking table, with a resultant mixing of meats and mud. When thus smeared with mud, the meats must be washed more vigorously and consequently will often break apart and produce an inferior pack.

A live mussel is much more difficult to open than a clam, and in the process, the meat usually is torn. Steaming causes the mussels to open and makes it possible to pick the meats out rapidly. The loss in weight from steaming is an advantage since it prevents excessive shrinkage later in the cans when they are processed. The mussels are steamed in a retort for eight to ten minutes at 240° F. A shorter period of steaming does not open all the shells. A longer period tends to toughen the foot and mantle.

The bouillon from the mussels can be included in the canned or frozen product, as it adds slightly to the food content of the pack. Comparisons indicated that the addition of bouillon did not seem to increase materially the flavor of the product. This liquid from the steamed mussels, if used, should be strained and clarified, for it has a very cloudy appearance.

After steaming, the mussels were taken to the shuckers who removed the meats from the shells and the byssus, or hair, from the meats. Preliminary tests showed that the total time needed to prepare a bushel of steamed mussels for canning was one-half that required for soft clams. It is not necessary to remove a tough siphon, as with the clams, and both the mantle muscles and the foot are tender. Special care, however, must be taken to remove the byssal hairs, which have an unpleasant appearance. In regions south of Cape Cod, mussels are often hosts to the mussel crab (Pinnotheres maculatus). This small crustacean, about ½ inch long lives commensally in the mantle cavity of the mussel and should be removed from the mussel meats during the shucking operation. Although the crab is edible and esteemed by epicures, its presence in mussel meats is not appreciated by the average consumer.

The shucked meats were washed in either salt or fresh water to remove any small amount of mud which might be present. The meats then were weighed into cans. The meats should not be soaked in either fresh or salt water prior to canning. This procedure, which is sometimes used for clams, results in such a decided loss of flavor within a few hours that the soaked meats are almost tasteless. The soaking toughens the mantle and foot muscles and furthermore softens the reproductive organs to such an extent that they may crumble. Consequently, with toughened and broken meats, the product is poor in appearance and texture.

Successful packs were processed by the canners at temperatures of 240° F. for 30 minutes in a No. 1 picnic can having a drained weight content of 6½ ounces of mussel meats. Quick cooling of the cans after retorting seemed to be desirable. Further studies on the technique of mussel canning have been carried out by the technological laboratories of the Fish and Wildlife Service.

According to scallop fishermen, large beds of horse mussels (Modiolus modiolus) exist along the Maine coast. In order to explore the possibilities of developing a fishery for this species, an experimental pack was processed at a cannery in Southwest Harbor, Maine, in July 1943. The mussels were dredged from submerged beds lying in about 40 feet of water near Jonesport, Maine. Horse mussels are seldom found in any abundance in depths of less than two or three fathoms. The lengths of the mussels on the Jonesport beds ranged from four to six inches.

The horse mussels were processed in the same manner as that used for Mytilus edulis, except that a retort time of about 17 minutes was necessary to open the shells enough for easy shucking. The meats, which were reddish-orange and somewhat tough, were packed in No. 1 picnic cans. Ten to eleven meats produced a drained weight of seven ounces after processing in the can. It was felt that this product would appeal less to the consumer than Mytilus edulis and no attempt was made to promote a fishery for Modiolus modiolus.

REGION

PART III - DEVELOPMENT OF THE FISHERY AND THE POSSIBLE NEED FOR CONSERVATION MEASURES

INTRODUCTION

This is the third and concluding paper concerning the North Atlantic mussel fishery. The two previous papers have discussed the efforts to determine the possible magnitude of a mussel fishery and then to assist in the development of the fishery. This article presents the history of the recent fishery and the role of conservation.

DEVELOPMENT OF THE FISHERY

The year 1942 marked the beginning of the mussel canning industry in New England. A small pack of pickled mussels was processed in May 1942 by a Maine cannery. In the summer of 1942, another Maine cannery packed a few cases of mussels as an experiment. At the same time, the Fish and Wildlife Service similarly was preparing some trial packs. In October and November, the mussel

A BED OF SEA MUSSELS, MARTHAS VINEYARD, MASS.

canning was still on an experimental basis. During December 1942, one cannery processed a total of 400 bushels, and an increasing number of cannery operators became interested in the potentialities of the mussel industry. In January 1943, representatives of the Fish and Wildlife Service held a meeting in Boothbay Harbor, Maine, to discuss the prospective mussel fishery as revealed by the survey.

Table 9 - Yield of Maine Mussel Fishery, By Counties, By Months[1]

Month	Counties					Value
	Knox	Hancock	Washington	Other	Total	
	Bushels	Bushels	Bushels	Bushels	Bushels	Dollars
May 1942	-	-	2/ 1,500	-	1,500	750
Total 1941-42 season	-	-	2/ 1,500	-	1,500	750
December 1942	-	-	400	-	400	150
January 1943	-	-	817	-	817	327
February 1943	1,264	2,205	1,198	-	4,667	4,667
March 1943	11,804	780	6,006	-	18,590	14,872
April 1943	5,157	30,177	807	-	36,141	28,913
May 1943	1,743	26,725	7,651	-	36,119	28,895
June 1943	-	3,724	7,237	-	10,961	8,769
Total 1942-43 season	19,968	63,611	24,116	-	107,695	86,603
November 1943	151	1,794	476	-	2,421	1,695
December 1943	4,630	15,243	2,641	-	22,514	9,006
January 1944	3,114	13,924	2,461	-	19,499	7,800
February 1944	5,162	13,569	3,383	-	22,136	8,854
March 1944	9,457	25,941	3,841	-	39,239	15,695
April 1944	12,680	37,858	1,693	3/ 1,497	53,730	21,492
May 1944	514	23,213	3,061	-	26,808	13,404
June 1944	-	-	1,681	-	1,681	504
Total 1943-44 season	35,538	131,442	19,357	1,497	187,828	78,950
October 1944	-	-	1,327	-	1,327	398
November 1944	-	4,189	1,377	-	5,566	1,948
December 1944	-	6,123	-	-	6,123	2,143
January 1945	-	12,941	-	-	12,941	4,817
February 1945	832	11,361	1,170	-	13,363	4,009
March 1945	1,343	15,553	4,195	-	21,091	6,327
April 1945	1,455	32,496	3,459	-	37,410	13,097
May 1945	469	27,396	5,463	-	33,328	13,331
June 1945	-	8,916	2,747	-	10,763	3,767
Total 1944-45 season	4,109	117,175	19,738	-	141,022	49,837
September 1945	-	-	1,042	-	1,042	325
October 1945	592	8,068	6,483	-	15,133	6,053
November 1945	1,264	16,711	5,288	-	23,268	9,307
December 1945	2,392	16,548	4,985	-	24,225	9,690
January 1946	1,648	14,346	4,720	-	20,714	8,286
February 1946	595	7,631	2,100	-	10,266	4,106
March 1946	548	30,945	3,089	4/ 4	34,580	13,832
April 1946	71	53,548	-	-	53,619	21,448
May 1946	-	14,349	562	-	14,911	5,964
Total 1945-46 season	5,068	162,146	28,269	4	195,688	78,951
October 1946	-	1,332	842	-	2,174	734
November 1946	-	-	890	-	890	267
December 1946	-	-	10,496	-	10,496	4,010
January 1947	-	546	-	-	546	218
Total 1946-47 season	-	1,878	12,228	-	14,106	5,229

1/ From statistical reports of the Maine Department of Sea and Shore Fisheries.
2/ This quantity credited to Hancock County through error.
3/ Lincoln County.
4/ York County.

Cannery operators and representatives of the Massachusetts Division of Marine Fisheries, the Maine Department of Sea and Shore Fisheries, the U. S. Pure Food and Drug Administration, and the Fish and Wildlife Service attended. The meeting provided the necessary facts for utilizing mussels, and shortly thereafter, with the seasonal increase in yield of meats per bushel, the onset of favorable fishing weather, and the presence of a promising market, there was a considerable expansion of the fishery.

Table 9 shows the yield of the Maine mussel fishery for six seasons. Similar information is not available for Massachusetts, but it is known that several thousands of bushels were packed in that State during both the 1943 and 1944 seasons. The Massachusetts mussels were obtained from Cape Cod and Buzzards Bays, while those in Maine were predominantly from the Hancock County region which includes the areas of Frenchman, East Penobscot, and Blue Hill Bays.

From Table 9, it is apparent that the three-month period, March to May, represented the peak of production in five of the six seasons. The primary reason for this seasonal peak was that the mussel meats were well developed during this period, and thus the cost of the raw material was lower. There are several reasons why the April pack was higher than that of May, when the meats were even heavier. Perhaps, the most important reason was that the canned mussel market was generally uncertain and canners were reluctant to have too great a pack of unsold mussels. During the spring months, the production greatly exceeds the immediate demand. In late May, some canners stop packing mussels because they are approaching the spawning period. As the gonads near their maximum development, the enlarged mantle is torn easily during the shucking or washing operation, and the meats have a poor appearance in the can. Still other canneries begin in May to process or make preparations for canning fish, and therefore, cease mussel packing.

The 1946-47 season shows a marked decrease in the mussel fishery. The primary reason for this abrupt decline from the previous season's production is that there was a carry-over of some of the 1945-46 pack and the canners were reluctant to pack any quantities until the extent of the postwar demand could be determined. Consequently, no mussels were processed during the 1947 spring season.

At the present time, a small but fairly steady demand for canned mussels has been established, but this was not always so. When the first large quantities of mussels were processed in 1943, the product was almost unknown to the American public. However, due to the shortage of other types of canned shellfish, wholesalers and retailers did not hesitate to purchase the pack. In 1944, there were reports that consumers were not buying the mussels, and that retailers were overstocked. The future of the fishery appeared to be uncertain, since brokers were becoming reluctant to handle the product.

Several meetings to discuss this problem were held by the mussel canners, the Maine Development Commission, the Department of Sea and Shore Fisheries, and the Department of Agriculture, and the United States Fish and Wildlife Service. Several important facts were revealed. First, some of the canned mussels were of inferior quality because of careless handling, and these inferior packs tended to discourage the future sales of mussels. Second, certain regions had developed into good markets for this shellfish, despite a lack of concerted advertising. While there was a recognized need for advertising, the canners were somewhat reluctant to finance a well-organized campaign. It was apparent that advertising would not be efficacious unless the entire mussel pack was of prime quality. The

establishment of standards for canned mussels was discussed, but no definite commitments were made by the packers.

Subsequently, some of the canners set up and maintained certain standards of quality, and carried on local advertising and demonstrations in various cities. These more energetic packers can be given the credit for increasing the sales of mussels after 1944. Lowered prices, improved quality, and a seafood of distinct merit were responsible for their success.

CONSERVATION

The production of mussels probably will be limited in the future by the available supply. In many regions, especially those in which the mussel beds were located in shallow water, it has not been difficult to deplete seriously the local supply of marketable mussels within a fishing season or less, especially when all sizes of mussels have been removed. Where the growth rate is slow, these depleted mussel beds may be rendered practically worthless for several years, until seed mussels have a chance to set and grow to marketable size. The stripping of mussels from the shallow water beds is relatively simple, for mussels, unlike clams, lie exposed on the flats. When it is apparent that the mussel population is being depleted, the possibility of applying conservation methods must be considered.

Regulation of the mussel fishery should be based on the need for utilizing the mussel resources to greatest advantage in order to maintain a sustained high yield. Obviously, mussel regulations would not be necessary because of any possible extinction of the mussel, for the fishery would be unprofitable long before extinction. Unfortunately, there are a great many factors affecting mussel population about which little is known. An optimum conservation policy cannot be formulated until an intensive study of the North Atlantic mussel beds is carried on to determine the relationship between natural and fishing mortalities; the growth and survival rates under various conditions, such as occur at various levels of the tidal range or on beds of different population densities; factors influencing spawning, larval drift, and the resultant setting of spat; and the practicability of transplantation to build up a depleted mussel area.

While there is not yet a clear understanding of all the factors influencing the establishment and growth of mussel beds, there are two measures which can be taken to assure that the present mussel resources are utilized to the best advantage. These regulations are:

(1) A closed season when mussel meats are thin.

(2) A minimum size law to eliminate destruction of young mussels.

It is understood, of course, that these two measures will not wholly prevent further depletion but they will, however, eliminate an obviously unwise utilization of the shellfish. Similar regulations are in effect for the soft-clam fishery.

A closed season when no harvesting could be done would prevent the use of mussels whose yield of meats is at a seasonal low. From the data accumulated at Friendship and Boothbay Harbor, Maine, it is evident that in the period July through March, mussels are relatively thin. For example, as shown in Table 6,[1] a bushel of Friendship mussels collected in the first week of December yielded 5.87 pounds of steamed meats. In the first week of April, a bushel yields 8.55

1/ See Part II of this article which appeared in the October 1949 issue of Commercial Fisheries Review, p. 13.

pounds, an increase of over 45 percent; while in the first week of May, a yield of 9.36 pounds would be obtained, an increase of over 59 percent. At Boothbay Harbor, a bushel yields, during the period July 8 to February 22, between 11.0 and 13.5 pounds of raw meats. In April, weight of the raw meats would have increased between 14 and 40 percent; in May, from 30 to 59 percent; and in June, from 43 to 76 percent. Thus, the practice of harvesting mussels in months other than April, May, and June is a wasteful one.

During the war years, every effort was made to encourage the canneries to process mussels. A closed time was not urged because a maximum production of sea food was needed and the canneries were best able to process this species during December to May, without interference with other canning activities. In 1942-45, due to both the need for protein food and the definite uncertainty of the future of this new product in postwar years, it was felt that a maximum utilization of mussels was justified even if it was necessary to use them when poorly meated. Figure 6 shows that a considerable portion of the catch of the three greatest seasons was taken before the mussels reached their prime condition.

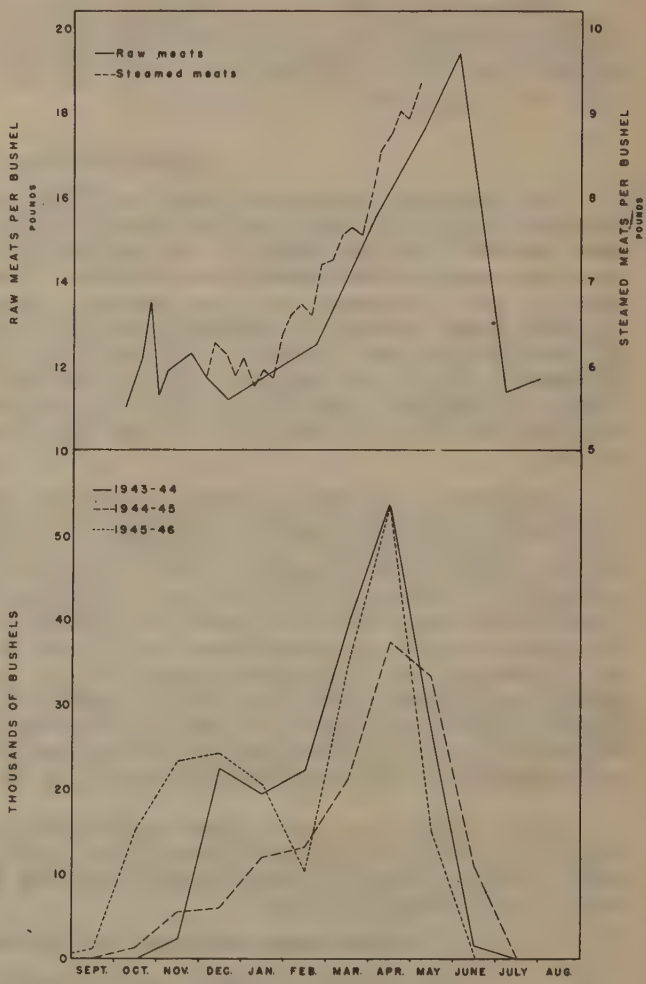

FIGURE 6 - THE SEASONAL YIELD OF RAW MUSSEL MEATS AT BOOTHBAY HARBOR, MAINE, AND OF STEAMED MUSSEL MEATS AT FRIENDSHIP, MAINE, AS COMPARED WITH THE SEASONAL PRODUCTION OF THE MUSSEL FISHERY FOR THREE SEASONS.

Because the mussel fishery in eastern Maine has developed to the stage in which actual local depletion of marketable mussels exists, it is advisable to propose a minimum size law which will protect the smaller mussels from destruction. It may be possible that after extensive study, a proposed 2-inch minimum size will be found too small, or perhaps even too large, to obtain the greatest continuous yield from a given mussel area. However, at the present time, some protection must be given to the mussels, or the yield from the mussel beds undoubtedly will decline further.

The Maine canneries insisted at the beginning of the 1943 fishery that the fishermen bring in no small mussels; the majority of all mussels purchased would have to measure between 2½ and 3 inches long. Small mussels were not desired because of the increased labor cost in obtaining a given volume of meats. This unofficial size limit put into operation by most of the canneries made it necessary for fishermen to obtain the mussels from below the low-tide mark, usually on the margins of the mussel beds, although the large mussels also were found submerged and clustered around ledges, islands, or rocks where growing conditions were favorable. The labor involved in culling the small mussels precluded the utilization of the mussel beds on which large quantities of smaller mussels existed. Although the mussels could be hand-picked from the beds, it was much more profitable to collect, by means of forks or clam hoes, the large mussels from two or three feet below mean low water, for those large mussels were relatively free of the smaller sizes and, consequently, little culling was necessary.

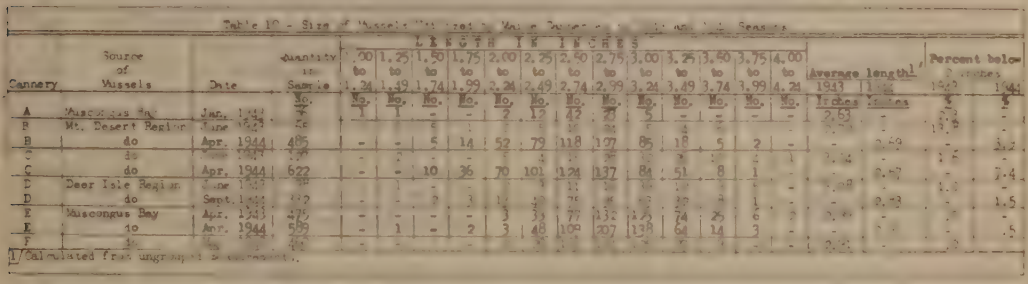

Table 10 shows the sizes of mussels used by Maine canneries in the 1943 and 1944 seasons. The average size ranged between 2.63 and 3.08 inches and the numbers of mussels under 2 inches were comparatively small. At two canners ("C" and "D") there was a very highly significant difference between the sizes of mussels used in 1943 and 1944. Cannery "B" shows a less marked decrease. There are two possible reasons for the decrease in size at these canneries. First, there could be a decrease in the availability of large mussels; and second, less strict culling by fishermen would result in a smaller average size. Probably both factors were important. Even though culling was less vigorous in 1944, 93 percent to 100 percent of the mussels were over 2 inches in length.

The mussels used by the canneries had been culled by the fisherman from his total catch; therefore, the sizes were not representative of the total drain on the mussel beds. Among the fishermen, the general practice has been to harvest the mussels and load the boats or scows during low tide. After the tide has risen over the beds, the mussels were taken ashore where the culling operation was performed, often under shelter. Those mussels which were undersized were not returned to the beds but were left on the shore where they soon died of exposure. The great mortality among these small mussels exposed to unfavorable conditions on the shore or upper part of the intertidal zone has been responsible for a common belief among fishermen that culling kills the small mussels.

An experiment was designed at Boothbay Harbor, Maine, to measure the effect of returning or transplanting small mussels to beds exhausted by commercial exploitation. Although transplantation is vigorously practiced wherever mussel culture is carried on in Europe, a practical demonstration of the value of returning small mussels to the beds was needed.

The area selected for this experiment was a small mussel bed near the Fisheries Station at Boothbay Harbor, Maine. This bed is in a cove sheltered from storms and relatively free from ice during the winter. In relation to mean low water, the experimental area (Figure 7) has an elevation of .6 to 1.1 feet on A_3, B_3, and C_3 plots, while A_2, B_2, C_2, A_1, B_1, and C_1 all had elevations of 1.1 feet. The only natural enemies observed in the area were sea gulls (Larus argentatus) and crows. At the termination of the experiment four mussles, all dead, showed perforations similar to those bored by Thais lapillus; however, this gastropod was not abundant in the area.

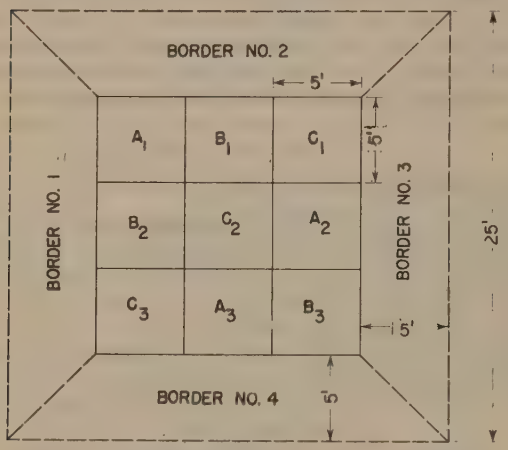

FIGURE 7 - DIAGRAM OF THE EXPERIMENTAL MUSSEL BED AT BOOTHBAY HARBOR, MAINE. MUSSELS WERE TRANSPLANTED TO A_1, A_2, AND A_3 PLOTS, REPLANTED ON B_1, B_2, AND B_3 PLOTS, WHILE C_1, C_2, AND C_3 PLOTS WERE LEFT BARE.

A 15-foot square of this bed was stripped of mussels on June 17, 1943, in a manner similar to that by which bed mussels are gathered commercially. The mussels measuring less than 2 inches were sorted out and 900 of these mussels, ranging in size from slightly under 1 inch to almost 2 inches in length, were marked by filing a short groove on one valve close to the umbo. Great care was exercised to prevent filing through the shell. The marked mussels were apportioned into three lots of 300 each and replanted June 21, 1943, on the B squares (Fig. 7).

At the same time, 876 mussels under 2 inches in length were gathered from a float at the Fisheries Station, marked on each valve with a filed groove close to the umbo, apportioned in 3 lots of 292 each, and transplanted to the A squares. The remaining squares were left devoid of mussels to serve as controls. The experiment was designed for 300 mussels on each of the A and B plots, but the supply of suitable mussels from the float was insufficient. The effect of the small difference between the number of planted mussels on the A and B plots should have little effect on the analysis of the experimental results.

As the transplanted mussels had relatively thin shells, the file marks had to be long and shallow or the shells would have been filed through completely. The replanted mussels, which had thicker shells, were marked with a short, much deeper groove. Thus, no problem of identification was presented when only one marked valve was later recovered. To determine the mortality resulting from marking, 40 mussels were marked in equal lots with one and two grooves and held for two weeks in one of the station's aquaria. No mortality was observed.

On December 21, 1943, the mussels were removed from the experimental area. The results are shown in Table 11. Since it was discovered that some marked mussels had shifted from one square to another during the course of the experiment, the area immediately surrounding the bed was examined on April 8, 1944, at which time, all mussels were removed from a 5 foot border around the experimental area. The numbers of marked mussels found within this area are also shown in Table 11.

As will be noted from Figure 7, the design of this experiment is that of a Latin Square, which tends to equalize the effect of conditions prevailing over the area and provides a standard method of analyzing the results.

An analysis of variance of the survival data in Table 11 indicates that no significant difference is apparent among the numbers of unmarked mussels entering the rows, columns, or types of plots. The center plot C_2 has the lowest number of unmarked mussels, as could be anticipated, due to that plot's being the farthest from any source of unmarked mussels. It must be remembered

Table 11 - Survival of Replanted and Transplanted Mussels on Experimental Bed

Plots	Date Planted	Number of Marked Mussels Planted	Date of Removal	Number of Marked Mussels Removed				Number of Unmarked Mussels Entering Bed
				Live		Dead		
				Transplanted Mussels	Replanted Mussels	Transplanted Mussels	Replanted Mussels	
A1	June 21,1944	292	Dec. 21,1944	231	9	14	9	357
A2	do	292	do	233	3	8	2	328
A3	do	292	do	206	1	12	0	363
B1	do	300	do	2	150	1	36	408
B2	do	300	do	0	151	0	22	282
B3	do	300	do	0	135	1	8	164
C1	-	-	do	0	7	0	3	505
C2	-	-	do	3	0	1	1	98
C3	-	-	do	3	1	1	0	212
Total	-	1,776	-	678	457	38	71	2,717
Borders:								
No. 1	-	-	Apr. 8,1944	1	5	2	5	-
No. 2	-	-	do	12	10	0	1	-
No. 3	-	-	do	10	21	3	8	-
No. 4	-	-	do	4	5	2	1	-
Total	-	-	-	27	41	7	15	-
Grand Total	-	1,776	-	705	498	45	86	-
Percent Survival	-	-	-	80.5	55.3	-	-	-

that the experimental bed is not exactly comparable to an area which has been commercially stripped of mussels. The experimental bed was immediately surrounded by an unexploited mussel area which could be the source of the unmarked mussels which entered the plots. Such a repopulating of a stripped area would not be as readily possible on a large area from which most or all mussels had been removed.

Since the greater part of the unmarked mussels found on the experimental bed were seed mussels, the numbers and average sizes of these small mussels were analyzed to determine the effect of the type of plot on spat setting. Any mussel on the bed with a length of .50 inches or less in December was considered to belong to that year's spat. No significant differences were found.

A highly significant difference is evident, however, between the survivals of the transplanted and the replanted mussels. This difference is readily apparent in the percentage survivals in Table 11--80.5 percent of the transplanted mussels had survived in contrast to a survival of 55.3 percent for the replanted mussels. No significant difference appears between the rows and columns of the bed.

Consideration of the data shows that the replanted mussels, both alive and dead, were recovered on the borders and on the plots other than those on which they were planted, about twice as frequently as were the transplanted mussels—46 specimens (5.25 percent) of the total transplanted mussels and 92 (10.2 percent) of the replanted mussels had strayed from their plots. Thus, part of the

apparent lower survival rate of the replanted mussels may have been due to migration from the bed and beyond the borders. Migration would also affect the recovery of transplanted mussels, but to a lesser extent. It is evident, however, that the replanted mussels suffered a greater mortality than the transplanted ones, for 9.6 percent of the total replanted mussels were recovered as dead, but only 5.1 percent of the transplanted mussels were found to have died.

A probable explanation of the different survival rates of the two lots is that the transplanted mussels were more vigorous than the replanted ones, and were able to adapt themselves better to conditions on the bed. In order to remain on the bed, the mussels would have to attach byssal threads quickly to other mussels and mussel shells or risk being carried off by tidal action. When the mussels were placed on the bed, few of them were attached to each other. Undoubtedly, the marked difference in survival warrants additional study and experimentation for clarification.

Table 12 - Growth of Marked Mussels on Plots

Date	Type of Mussel	Quantity in Sample	LENGTH IN INCHES									Average Length[1]	Average Increase	Percent above 2 Inches
			0.75 to 0.99	1.00 to 1.24	1.25 to 1.49	1.50 to 1.74	1.75 to 1.99	2.00 to 2.24	2.25 to 2.49	2.50 to 2.74	2.75 to 2.99			
		No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Inches	Inches	%
June 21,1943	Transplanted	96	-	9	31	27	21	2/8	-	-	-	1.597	0.475	3.3
Dec. 21,1943	do	678	-	-	7	46	185	294	128	16	2	2.072		64.9
June 21,1943	Replanted	151	10	33	41	32	26	2/9	-	-	-	1.476	0.450	6.0
Dec. 21,1943	do	457	-	1	8	86	203	120	37	2	-	1.926		34.8

1/ Calculated from ungrouped measurements.
2/ These mussels measured between 2.000 and 2.032 inches.

Analysis of the data on growth of the mussels does not reveal any significant difference between the rate of growth of the two lots of marked mussels. Neither is there any apparent difference between the growth increment of the marked mussels found on the plots and on the borders. The replanted and transplanted mussels grew at about the same rate during the 6-months period that they were on the bed and border, as shown in Table 12.

The mussel bed experiment has demonstrated that, under conditions prevailing on a Boothbay Harbor mussel bed, small mussels returned or transplanted to the bed have a relatively high survival. This refutes the oft-heard statement that replanting mussels is always useless because of the ensuing high mortality.

A minimum size regulation of two inches could be readily applied, easily enforced, and would be of little inconvenience to the fisherman. After culling, he would hold the small mussels in burlap bags suspended in water or put them into submerged crates. On the following day or soon after, the mussels could be returned to the beds from which they were taken. As indicated in the results of the planting experiment, most of the small mussels between one and two inches would be ready to harvest either later in the same season or during the next season. The minimum size regulation would be most applicable to the Maine beds; in Massachusetts, the problem may be quite dissimilar, for in 1942-43, only large mussels existed on the commercially important beds in Cape Cod Bay and Nantucket Island.

The mussel fishery has great potentialities and every effort should be made to insure that the resource is not misused. It is only by further study and by the utilization of conservation measures based on such study that this shellfish resource can be maintained or increased.

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